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BULLETIN

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OF

DENISON UNIVERSITY.

EDITED BY
C. L. HERRICK, M. S.,
PROFESSOR OF GEOLOGY AND NATURAL HISTORY.

GRANVILLE, OHIO:
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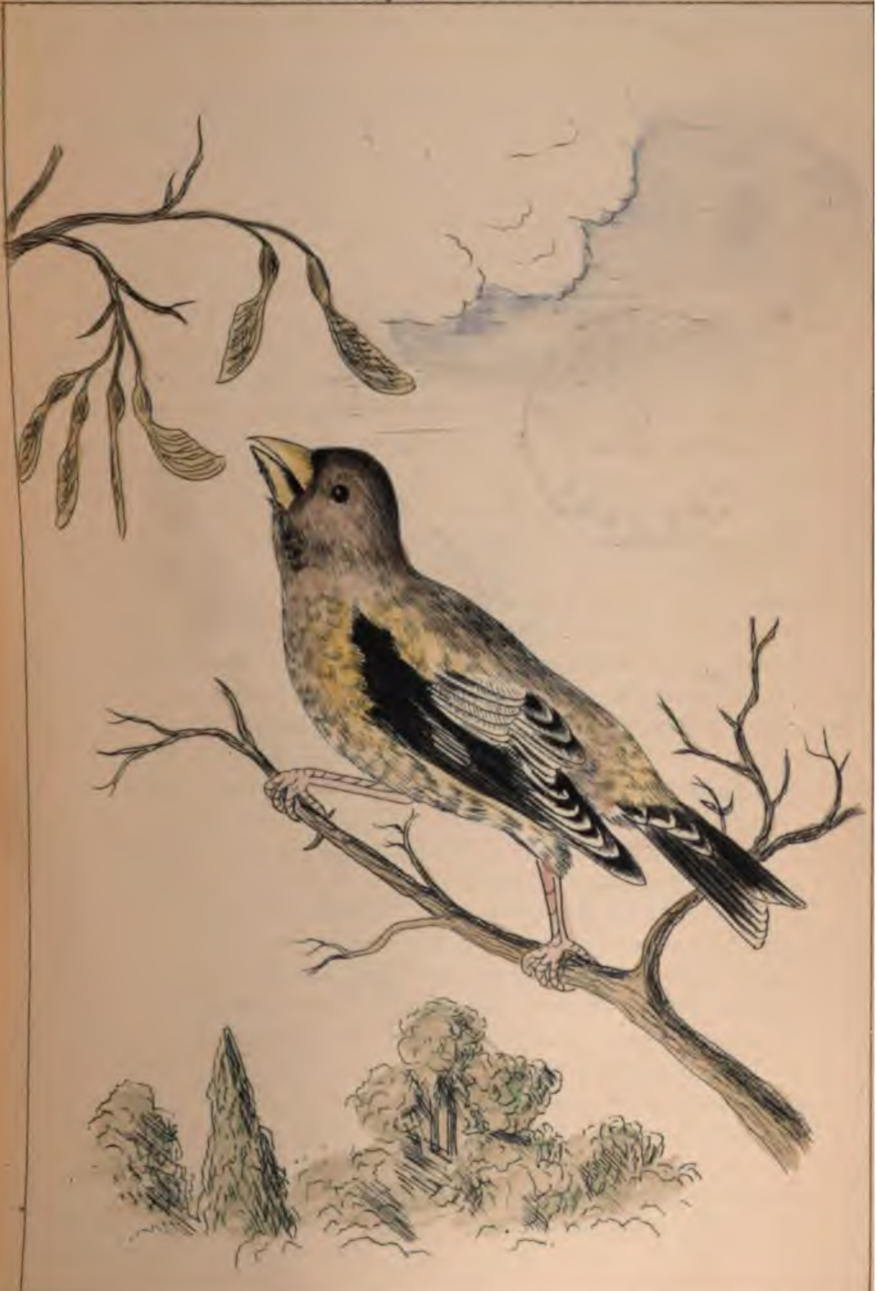

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A considerable number of papers prepared for this number have been necessarily delayed, on account of the limited space allotted, and yet our limits have been extended. The lithographs were executed by the editor and printed by a process making them cheaper than any other available, and any failure to realize the ideal of such work will, no doubt, be pardoned on this account.

For information relating to the departments here represented, the reader is referred to the advertisement appearing elsewhere. The fact that the chemical laboratory has afforded us no material for this number, may be attributed to the change in administration in that department, occasioned by the death of the lamented Prof. Osbun.

I.

THE EVENING GROSBEAK—*Hesperiphona vespertina, Bonap.*

[Plate I and Frontispiece.]

Among the rarities in the cabinet of most ornithological collectors is the Evening Grosbeak, which excites interest as much by its comparative rarity and exceeding capriciousness in distribution as on account of its odd note and eccentric behavior. First found by Mr. Schoolcraft, in 1823, near Sault St. Marie, in Michigan, it was described by Cooper. The indefatigable naturalist, Sir John Richardson, encountered it upon the Saskatchewan, where seems to be its natural home, and from whence it issues forth, guided by any whim, and wanders far to the East and South, though seeming to avoid the coast. The genus is Asiatic and our two species are obviously derived from the Old World, via Alaska. In Europe there is a closely allied genus *Coccothraustes*, which differs in the shape of the secondary wing feathers. The genus is distinguished from all other finches of the United States by the very large beak and the following points:

> " Feet short ; tarsus less than the middle toe ; lateral toes nearly equal, and reaching to the base of the middle claw. Claws much curved, stout, compressed. Wings very long and pointed, reaching beyond the middle of the tail. Primaries much longer than the nearly equal secondaries and tertials ; outer two quills longest ; the others rapidly graduated. Tail slightly forked ; scarcely more than two thirds the length of the wings, its coverts covering nearly three-fourths of its extent."—*Baird.*

[In America we have the two species, *H. vespertina* (with its two varieties), and *H. abeillii*, Scl., which lives in the mountainous portions of Mexico, southward.]

In very few places in the United States does this bird appear with sufficient constancy to be set down as more than an accidental visitor. In this respect Minneapolis, Minn., is particularly favored for, during a number of years, these grosbeaks have rarely failed to make a longer or shorter winter visit, sometimes coming early in the Autumn and remaining until the trees are in full leaf, when, in a few cases, their much mooted song has been heard. The most eastern point yet reached by these birds seems to be Cleveland, Ohio, and isolated cases of their occurrence in Wisconsin and Illinois are also known. The species is highly gregarious and individuals are rarely or never met with singly. Even the destructive inroads of the collector, before whom they are absolutely defenseless, do not scatter or break up the flock. Unsuspecting and without fear, they continue to feed until the last individual falls a victim. The migrating colony seems well satisfied with itself and its temporary home and, while feeding, a constant chorus of answering cries is kept up. The note is not loud but is remarkably piercing, and yet not unmelodious. The early belief that these birds are silent except at evening is entirely erroneous. In spring, upon the approach of the breeding season, the males cultivate the muses in an odd but not displeasing little song. This song consists of several successive repetitions of a short warble, followed by a similar strain closing with a shrill cry, like the finale of a black-bird's song. The phrase which makes up the body of the song is musical, but is so abruptly terminated (as though from lack of breath or of ability,) that it is annoying when heard singly, for one is subjected to much the same nervous expectancy felt in listening to a hen's cackle when quite leisurely "working up the agony" sufficiently to sound the final note. A flock of a dozen or more singing together produce a very musical effect. The food almost entirely consists of the seeds of various trees, among which the box elder, the maple, poplar, and pine are pre-eminent. Buds of cherry and other trees are also eaten, and this regime is varied by occasional insect larvae, etc.

O. B. Johnson, who mentions this grosbeak from the Williamette valley, speaks of it as plentiful during migrations, and states that "the only note heard was a loud '*yeeip*,' strikingly like the call of a lost chicken." Of the nest and eggs we as yet know nothing, and so of the many interesting traits which make up the sum of its true home-life we must be content to remain ignorant. From its inaccessable summer home it continues to descend during the severe winter weather and, almost under the very roofs of the factories of a busy city, contentedly passes the short days, heedless of the noise and regardful only of the oily kernels of the keys of the box elder, which it displays a very awkward skill in plucking as it swings (head downwards or otherwise) from the pendulous branches.

These brief remarks are designed simply as introductory to the notes on the osteology appended. Before preceding to these the following description will suffice to make the bird recognizable.

Sp. char. Bill, yellowish green, dusky at base; anterior half of body dusky yellowish olive, shading into yellow to the rump above, and the under tail coverts below. Outer scapulars, a broad frontal band continued on each side over the eye, axillaries, and middle of under wing coverts, yellow. Feathers along the extreme base of bill, the crown, tibiae, wings, upper tail coverts, and tail, black; inner greater wing-coverts and tertiaries, white. Length, 7.30, wing, 4.30, tail, 2.75. In the female the head and back is dull olivaceous brown. Below, the body is pale yellowish ash. There is an obscure black line on either side the chin. There is more white upon the wings and tail. (See plate, which is intended to give simply the *tout ensemble* without strict accuracy as to color.)

Osteology of Hesperiphona vespertina.

The anatomy of the Evening Grosbeak is of more than usual interest, not only on account of the rarity of the bird and the air of mystery which has associated itself with it, but because it stands at the head of American *Fringillidae*, by virtue of possessing the extreme development of the finch type of structure. Our observations are based on the study of three more or less perfect skeleta, which, so far as we know, are the first which have been studied.

The skull. The most striking peculiarities of the skull are those which are corelated with the extraordinary development of the beak. The angle, for instance, formed by the quadratojugal-jugal bony pillar with the lower margin of the maxilla is greater than usual, chiefly on account of the great size of the quadrate bone. In this way a firm support is afforded to the upper jaw. But we pass to a detailed description. As seen *from above*, the skull is, in outline, a perfect triangle, with a narrow rounded base. The apex of the triangle is formed by the remarkably large and strong (though correspondingly very light) beak. The bones entering the beak are cancellated within, forming a firm but light organ. These bones are, first, the *premaxilla*, which makes up the bulk of the bony frame-work of the beak and is early anchylosed with the maxillaries in the family under consideration. Although we can not separate the parts, we may distinguish in the *maxillary* bone a superior or nasal process which separates the opening of the nares and unites with the nasal bones, two lateral or maxillary processes, and two palatine processes which are within the mouth-opening. The distance from the apex of the beak to the subcircular nares is .6 inches, the distance between them, .10. The *nasals* are inseparably

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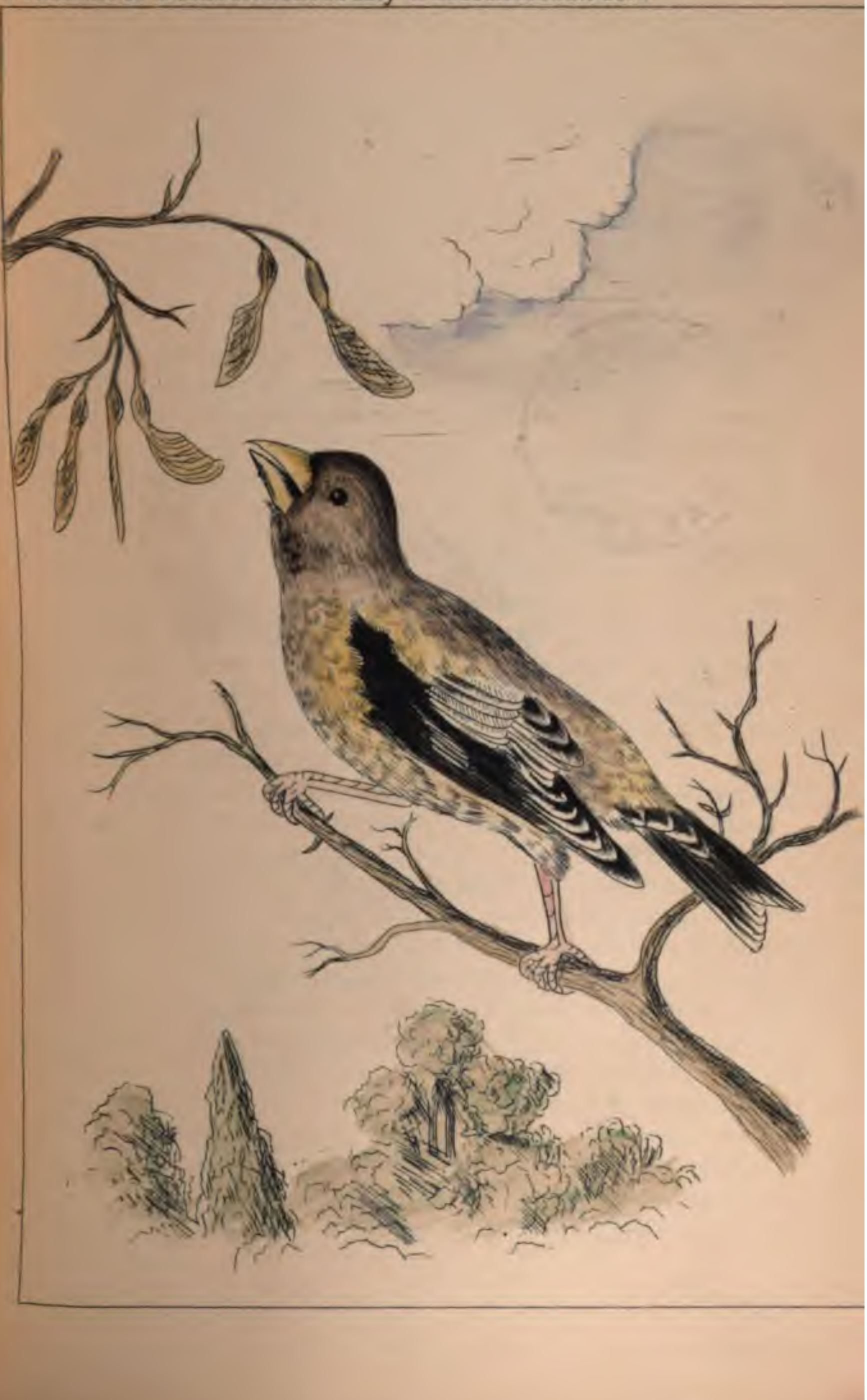

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united and form a quadrate bone making an angle of 25° with the culmen or upper line of the beak, their combined width is .45, and they form the posterior borders of the nares, being united laterally with the maxillaries, anteriorally with the intermaxillary, below with the lachrymals, and posteriorly with the frontals. The distance from the angle of the mandible to the top of the nasals is .40. Occupying the top of the skull, and apparently restricted to the space between the orbits, are the concave *frontals*. The distance between the orbits is about .35. The remainder of the roof of the skull is formed by the confluent *parietals* which occupy a larger area than usual on the top and back of the skull. From above can be seen a small prominence behind, which covers the cerebellum, and hence is called the *cerebellar prominence*. The sides of the triangle are continued backward from the ends of the maxillaries by a slender rod consisting of the *quadratojugal* and the *jugal* which can be studied to advantage when the skull is viewed *from the side*. In this position the skull is seen to present the outline of two triangles, the smaller of which, forming the beak, is set at an angle of 45° with the other. The cutting edges of the jaw (*tomia*), supported chiefly by the *maxillary* bones, are slightly curved. The tomia are .80 long. The slender rod passing backward and downward and forming the lower outline of the second triangle is, in the young, composed of two bones, the jugal and quadratojugal. Their combined length is .54, the posterior articulation being upon the outermost process of the peculiar *quadrate* bone. This bone is considered the homologue of the little ear bone of mammals, known as the malleus, but in birds has a very important function—that of giving the necessary movability and yet stability to the beak. It is the point of attachment of the two important supports of the facial part of the skull. The form of the quadrate is very irregular, consisting of a body and six processes. The styloid process is the largest and is that which connects the bone with the base of the skull ; it is a flattened vertical pillar with a large articular surface; jutting out anteriorly is the orbital process, about .30 long, which extends into the orbit. Just below the orbital is the pterygoid process of rather small size. The mandiblar end bears two curved processes so situated that the glenoid surfaces oppose the rami from within and behind, while the jaw is completely locked by the large articular process of the mandible. A more complete articulation could scarcely be conceived. The malar process extends out horizontally and offers an oblique surface to the head

I.

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At the posterior of the two mandiblar processes of the quadrate bone is a bone as large as the head of a large pin, but of irregular shape, which may be regarded as either a sesamoid contributing to lock the jaw or an independent portion of the quadrate. There is also a very minute sesamoid at the union of the quadrato-jugal and the quadrate. The lower jaw shows no evidence of its composite character. The whole anterior half is enlarged and forms a simple trough of cancellous bone which may be assumed to consist of the dentary elements of both rami. The surangular, angular and splenial elements of the rami are not distinguishable. The articular portion consists of a huge flange, extending inward and upward and is perforated at the middle of its inner surface for the entrance of Meckel's cartilage.

What corresponds to the surangular portion is a broad triangular plate extending upward inside the jugal bones and serving to further lock the jaw. Thus, as we have seen, the whole skull is modified in harmony with the enormous rhinencephalic development.

The *hyoid arch* is well developed and consists of seven bones, whose homologies, in the present state of our knowledge, cannot be made out. The anterior pair are pointed before and behind and attached at the middle to each other and the end of the azygos bone which next follows. The first mentioned bones are called *entoglossal*, by Gegenbaur, by some American authors, *ceratohyals*, with no real evidence that they are homologous with the bones so called in other animals. The following element may be called *basihyal* (*copula* of Gegenbauer,) and is flattened to form a vertical plate and bears on either side, posteriorly, the *cornua*, which each consists of one straight shaft, .50 long, and a shorter fusiform segment. Between these the *urohyal* extends backward as a support to the trachea. The atlas and axis are fused together more or less fully. There is no neural spine on the *atlas*, but its dorsal surface is perfectly plane. The *axis*, or second cervical vertebra, has a well developed spine and posterior zygapophyses and also a very large haemal spine, which curves backward. The *third cervical* has a smaller neural spine and its posterior zygapophyses project upward. Its haemal spine (hypapophysis) curves forward. There is a slight inferior lamella of its transverse process. The *fourth cervical* introduces a new type, having a low spine, nearly horizontal posterior zygapophyses, and elongated styloid inferior lamellæ. It has a smaller hæmal spine. The following cervicals have no neural or hæmal spines, the posterior zygapophyses decline, and the styloid appendages are very long. The thirteenth and fourteenth (last) cervicals have *pleuropophyses* (ribs), those of the former being mere rudiments, while those of the latter are large but have no connection with the sternum. These vertebræ, in common with the first of the dorsals, have strong hæmal spines. They also have the *capitula process* well developed to receive the head of the rib. The transverse process has its normal *tubercular facet* to sustain the tubercle of the rib. There are six *dorsal vertebræ*, which are more or less firmly co-ossified. The transverse processes are large and the spines of uniform size. The last dorsal is firmly united with the following nine vertebræ, which form the vertebral framework of the sacrum. Seven free vertebræ follow, forming the free *caudal* series. Each of these has a strong transverse process and a more or less perfect neural spine. Upon the last two there are also haemal spines. The last bone or *pygostyle* is remarkable for the great development of its neural spine.

The sternum is normal for the group and is 1.20 inches long. The keel is well-developed, being .50 high. The mid-xiphoid process is .40 wide at the end. The lateral xiphoids are separated by an excision one half as wide and rather more than .40 deep. The transverse sternal angle (that between the two sides of the body of the sternum,) is sharp and considerable. The costal processes are strong, while the coracoid grooves are .25 in width. The manubrium is particularly large and is bifid. Each of the six ribs, as well as the last cervical rib, has a well developed uncinate process.

The strongest bone in *the shoulder girdle* is the *coracoid*, which is expanded below and obliquely winged for a short distance, then is cylindrical and then curves inward, throwing off a flange-like process where the scapula is articulated, and ends in an articular surface against which the flattened upper part of the clavicle is pressed. From the lower angle of this surface a strong tendon passes to the process of the manubrium on that side. The *clavicles* are of the usual form, forming the merry-thought in connection with the anchylosed interclavicle. The *scapula* is united to both clavicle and coracoid and with the latter furnishes a glenoid surface for the humerus. Between these three bones, at their union, is a cavity, *foramen triosseum*, permitting the passage of the tendon of the sub-clavius muscle.

The *anterior extremity* is of moderate size. The *humerus* is .95 long and is much expanded proximally where it is .33 in breadth. The radial crest is short and quite prominent. The ulnar tuberosity is very large and outwardly presents a large triangular surface and within excludes two extensive fossæ, divided by a strong septum, from the end of which a strong process is developed. The opposite or distal end of the humerus is less highly developed, but still shows a high degree of perfection of the spinous appendages. The trochlea, consisting of the radial and ulnar tubercles, are about as usual. The radial condyle is a small prominence directed forward at the base of the radius, while the ulnar condyle is a larger acute process, extending in the opposite direction. The *radius*, the smaller bone of the arm, is but slightly curved and measures 1.20 in length. The ulna curves considerably, proximally, so that the sigmoid cavity is quite oblique to the shaft, and the olecranon process is small and styloid. The carpus contains two bones which have the usual positions. The *ulnare* is applied to the back side of the ulna and rotates upon its smooth articular surface. The *radiale* caps the ulnar and is overlapped by the radius in front. The three metacarpals are fused at the base. The first one can not be distinguished and its phalanx measures but .20. The second metacarpal is .65 long and is fused at both ends with the slender third metacarpal. The second digit consists of two phalanges, the first of which is .30 long and consists of two bars connected by a thin plate of bone, the second being a triangular plate .15 long. The third digit consists of a styloid phalanx .20 long. (The two ossicles described by Schufeldt, in certain birds, as the *cuneiform* and the *pentosteon*, are not discoverable in any of the skeleta before me.

The *pelvis* is papery and yet very complete. The obturator fissure, separating the *ischium* and *pubic* moiety of the pelvis is divided into an elongated posterior and smaller circular anterior foramen. The ilio-siatic foramen is quadrate, with rounded angles. The pubic bone is produced into a slender curved process, as usual in this group. The femur is .91 long and nearly straight and requires no description.

The *tibia* is a symmetrical straight bone, 1.30 long, while the fibula is nearly free from it and is about half its length. In the skeleta of adult birds, such as those before us, it is useless to attempt to distinguish the tarsal bones which unite with its epiphyses, thus forming the *tibio-tarsus*, nor yet the composition of the succeeding segment of the leg, the *tarso-metatarsus*. The latter is .80 long and is furnished with a strong process ("calcaneal,") behind, which is at present causing so much discussion. The subdivision at the distal extremity into the four metatarsals is distinct. The first of these, the *hallux*, is provided with a separate matatarsal, the *accessorius*, which is quite large and descends to the level of the other united metatarsals. The phalanges of the hallux are two in number, the first being very large, .32 long. The claw borne by the following phalanx is the strongest on the foot. The second toe has three phalanges, the third, four, and the shorter fourth, five, as is the case in all of the present group of birds.

Such a bare description as is above given of points in the osteology of a species of bird, is of little value, except as furnishing a basis for comparison with others of its own and other groups. Such a comparative study we cannot at present attempt, but may, perhaps, profitably note some points of difference between the present species and others of its own family, *Fringillidae*. Quite at the other extreme of the family may be found the genus *Pipilo*, which is represented in our region by the Chewink or Ground Robin, *P. erythropthalmus*, a bird of singular appearance, in some points resembling the Orioles, while mimicking the habits of the Brown Thrush. A comparison with this species then may be expected to give us the limit of divergence in structure within the family, and those points which are identical in both may, with some probability, be assumed to be of family, ordinal or class rank.

The skull is of very different form, but the differences are chiefly those accompanying the reduction in the size of the beak, which in the Chewink is slender, almost Icterine. This slender pointed beak does not extend backward so far as in the true Finches, but the malar pillar is much longer and the angle of the beak and the end of the tomia are forward from the orbit. The opening of the nares is much larger and the lachrymo-nasal space is a very large triangular opening. On this account the ascending process of the maxillary is quite slender. As seen from above, the skull of *Pipilo* is much narrower between the orbits and the facial portion of the skull is easily distinguished from the cranial. The orbits are rather larger and not nearly as well guarded. The lachrymal is of the same shape, but lacks the long slender process directed backward, below. The lachrymo-nasal foramen is small. The interorbital septum is very poorly developed, two oblong foramina extending longitudinally leave but a narrow bridge between them. The ethmoid is therefore greatly reduced. The back of the skull is alike in both, but the opening of the bullæ is directed more forward. The palatal bones are quite similar, but the posterior processes are not bifid. Two curved slender rods, which seem at least partially ossified, pass from the palatal processes of the maxillary to that part of the palatals farthest forward and highest. The pterygoids are of the usual shape and are flattened anteriorly to slide over the sphenoids The quadrate is smaller and of the same form, but has a rather longer orbital process, proportionally. The quadrato-jugal has the same hamular process posteriorly as described in the Grosbeak. The lower jaw is, like the upper, rather weak. The various parts entering into each ramus are indicated by the presence of a large oval foramen separating the surangular, angular and splenial, and the flange of the articular is large. The differences in the shoulder and arm are slight and are such as might occur in species of the same genus. The sacrum is relatively much stronger and the spinous armature is greater, this corresponding to the greater demand upon the muscles there finding origin. The foramina are of the same number, but the lower one is more elongated to correspond to the greater development of the pubic bone. The femur is of ordinary form, but the tibiotarsal segment is greatly enlarged. The fibula is quite well developed and is anchylosed with the tibia about one half an inch from the head, for a short distance, but is free above and below. The head of the tibia develops two huge processes and there is a small patella. The condyles are very large. The " calcaneal " process, strangely enough, is very small and poorly ossified. The foot itself is not particularly enlarged.

The form of the sternum is very closely alike in these birds ; in

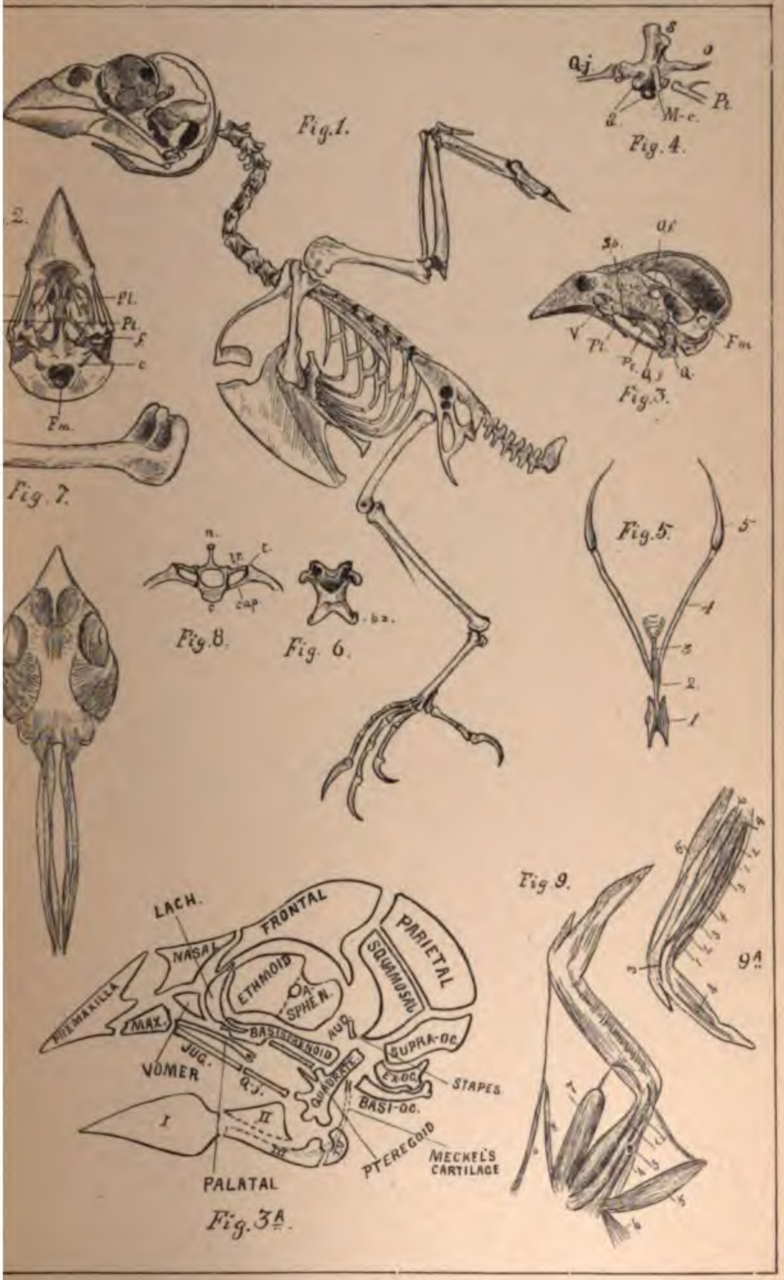
Fig.1.
qj
s
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Fig.4.
2.
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Fig.3.
Fig.7.
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5
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Fig.8.
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Fig. 6.
Fig 9.
9A
LACH.
FRONTAL
PARIETAL
NASAL
SQUAMOSAL
ETHMOID
OR.
SPHEN.
PREMAXILLA
MAX.
BASISPHENOID
AUD
SUPRA-OC
JUG.
VOMER
Q.J.
QUADRATE
EX-OC.
STAPES
BASI-OC.
I
II
III
PTEREGOID
MECKEL'S
CARTILAGE
PALATAL
Fig.3A.

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fact, the sternum is a valuable osteological index, for, not only is it pretty constant in a given family, but it presents points of constant difference between many families. The manubrium is larger, if anything, than in the Grosbeak.

Such are some of the differences noted between these species and they may be taken as indications of those points in the osseous structure most readily responding to changes in habit or habitation as induced by changes in the environment. It is by the elimination of the variable elements of different degrees of constancy that classification can be placed upon a permanent and correct basis. The variable points may be employed in distinguishing species, genera, etc., in accordance with their relative permanence or value.

PLATE I. *Anatomy of Hesperiphona.*

Fig. 1. Lateral view of entire skeleton.

Fig. 2. Skull seen from below. *Qj*, quadratojugal; *Pl*, palatal; *pt*, pterygoid; *sp*, sphenoid; *c*, condyle; *Fm*, foramen magnum; *L*, internal flange of mandible.

Fig. 3. Transverse section of skull *V*, vomer; *Q*, quadrate bone; *Of*, optic foramen; other references as above. 3*A*, diagram of bones of skull.

Fig. 4. Quadrate bone and articulations *Pt*, pterygoid; *Qj*, quadratojugal; *a*, accessory ossicles; *m c*, sheath of Meckel's cartilage.

Fig. 5. Hyoid arch.

Fig. 6. Superior surface of a cervical vertebra.

Fig. 7. Humerus.

Fig. 8. A dorsal vertebra, from behind.

Fig. 9. Muscles of the wing seen from above.

Fig. 9*A*. Anterior part of wing from below.

Fig. 10. Skull denuded of skin and showing certain cervical muscles.

II.

METAMORPHOSIS AND MORPHOLOGY OF CERTAIN PHYLLOPOD CRUSTACEA.

[Plates V—VIII and Plate X.]

The group *Phyllopoda* is one of the most remarkable among crustaceans, on account of the peculiar form and life history of most of its members. About the animals of this group there clings a certain air of mystery which may lead one to regard them as almost "uncanny." A pool by the wayside is suddenly formed by a shower and almost instantly becomes populated with a swarm of animal life, which no one ever saw there before and for the like of which we might search an hundred miles in vain. In a few days the little tragedy is played and the uncouth actors have disappeared, no one knows whither, having sown the clay at the bottom of the now dry pool, with eggs which, under favorable circumstances, may again put the play on the boards, but only after being themselves thoroughly dried by the sun. In short, in the study of these animals the unexpected is always appearing and known laws, or at least theories, are again and again negatived. We calmly institute a species when, lo! the change in certain conditions attending the development occasions the change to an entirely different genus in our system.

(See V. Siebold, in *Sitzungsberichte d. math.-phys. Classe zu Muenchen*, 1873, and the paper by Schmankewitsch in the *Zeitschrift fuer Wissenschaftliche Zoologie*, XXV Suppl., 1875.)

In spite of many able papers and works on American Phyllopods (notably the monograph, by Prof. Packard, in *The Geol. Surv. Terr.*, 1868, *Part I*, *Sec.* 2.) many points of deepest interest remain to be cleared up, and particularly such as relate to the development history and homologies of organs. In the present paper a few observations made some years ago, are presented with no attempt to discuss their bearing upon the questions in dispute. The student conversant with the literature of this subject will observe, however, that these facts make necessary a modification of views at present in vogue in several important particulars. The work was arbitrarily closed by circumstances and the material was long suppressed, in the hope of continuing a study which proved of absorbing interest; but, as this hope is now extinct and no motive remains for further delay, the observations are presented in their necessarily fragmentary form, hoping to fill a place in the life-history of these remarkable animals.

The Phyllopoda are extremely well adapted for use in biological laboratories and the outline here given may make the process of development plainer to the student who is fortunate enough to be supplied with such material for study. The two animals described may be found in early spring and late summer, in many temporary pools throughout the eastern zoographical province of North America.

A. Larval Development of Limnetis gouldii, Bd.

Limnetis is a genus of the FAMILY LIMNADIADÆ of Baird, which includes crustaceans enclosed in a bivalved shell, within which is concealed a body like that of a Water Flea, but having ten to twenty-seven pairs of leaf-like swimming feet. The very large head projects from between the valves in front and is flanked on either side by a biramose second antenna, while the first pair of antennæ is very small. A figure of the adult of the present species will be found in the monograph by Dr. Packard, and also in a paper by the present writer, in the 10th Annual of the Minnesota Geological Survey.

The earliest stage seen (Plate VI, Fig. 2.) was the simple nauplius-form common to all this group of crustacea, but so curiously modified as to at first almost defy recognition. The animal, as viewed from above, seems covered almost entirely by an oval shield, which is thickly studded with spines arranged in anastomosing lines. The head extends into a frontal prominence, which is densely bearded. The posterior part of the body forms a blunt prominence, bearing two spines. The eye, occupying the front of the head, consists of a single pigment fleck, with at first a single lense (?). The digestive tract is simple and similar to that of other Phyllopod larvæ. In the protuberance which represents the future abdomen, the muscles producing the pumping action of the rectum are well developed and anal respiration at once begins.

The appendages differ only in form from those of other larvæ. The antennules are long and curved prolongations of the frontal region and project laterally. They are covered with a spiny cuticle, like the antennules of the nauplius of *Chirocephalus*, but are less movable and less obviously tactile organs. It has been denied that these are really antennæ, but the history of their further development makes it clear that they are really representatives of those organs, though obscured by their covering.

Although the nauplius of Limnetes is said by authors (Packard, Monogr. Phyllopod Crust, etc.) to be distinguished from other nauplii by the small size of the labrum, this is founded upon a mistake. The labrum is really the most prominent of the larval organs. It is, indeed, of monstrous form and is so enlarged as to become a valve nearly as large as the shield-like expansion of the body above. The larva resembles a small turtle, from the edge of whose shell protrude two pairs of appendages.

The labrum is thorned, as is the whole body, and is slightly, if at all, movable. In this respect it differs little from other young nauplii. Like the first pair of antennæ, the labrum is obscured by its larval envelope, similar to that which extends the carapace of the body to form a false shell. The second antennæ are of the usual form among Phyllopods, the anterior branch being five-, the lower one two-jointed. The basal portion is furnished with a prominence bearing two heavy claws. The palp of the mandible is of the usual form.

In the next stages slow changes accompany the increase in size. A dorsal area is marked off over the maxillary and mandiblar segments, from which the shell develops under the larval covering. The nauplius eye becomes associated with a pair of club-shaped sensory hairs. A ventral swelling becomes distinct and proceeds to segment itself and elaborate limbs. (Fig. 1, Plate VII.) In figure 11 of this plate, which gives a semi-diagramatic under view of the abdomen, is shown that, as in other Phyllopods, the appendiculate segments seem to appear at once and the development goes on then from before backward. Prior to the appearance of feet (stage of Fig. 1.) the animal is about 0.33 mm. long, but becomes over 0.50 mm., before the metamorphosis. In the last stage prior to assuming the characteristics of the adult, the antennules seem smaller, the labrum has become cordate and very wide, while a prominence appears below the eye. Rudiments of the compound eye are visible and the sensory filaments overlying the pigment fleck are developed. The anterior part of the digestive tract has bifurcated and its branches extend toward the labrum.

The accessory branch of the second antenna, with its forceps, has become large. Now the hypodermic contents of the antennules withdraw from its shell and compact themselves into the mature form, developing, at the same time, sensory rods in their substance. The contents of the labrum fall away from the walls and gather into a lobe-like body. Feet have formed, and a single-chambered heart is actively pulsating. The future shell may now be seen under the larval covering, connected only with the back over the segments bearing gnathites, and hanging free about the edges. When the moult is affected the labrum falls within the valves, carrying with it the small tactile antennules, which hang pendant by a slender stalk. The frontal prominence, however, is elongated, forming the beak. The larva is now a diminutive of the adult. In its future development the form elongates and finally again becomes rounded and assumes the familiar appearance. The branches from the stomach fill the front of the head with so-called liver-lobes. The compound eye becomes perfected, while the nauplius eye is covered by filaments charged with some unknown sensory function. The heart becomes multi-chambered and the genital organs appear. For a figure of a young Limnetes, see *Types of Animal Life, etc.*, by the author; for figures of the adult and a discussion of relationships, see Packard's "Monograph of the Phyllopod Crustacea of America"; *U. S. Geol. Surv. of Terr.* 1878, *Part I.*

Farther details may be gathered from the plates. It is a matter of regret that Grube's work on the development of the European ***Limnetes brachyura*** was not accessable to me during the period which was covered by this paper. My recollection is, however, that the processes are, in the main, identical, but that Grube fails to identify all the organs of the embryo.

B. Post-embryonic Development of Chirocephalus.

The species studied is assumed to be the common *C. holmani*, Ryder, although the oldest male seen differed in several particular from the description of that species. One must imagine a fish-like, transparent animal, about one-half inch long, balancing itself in the water by the movement of eleven pairs of lamellate swimming feet. The colors are brilliant and do not interfere with an almost perfect transparency of the body.

The earliest stage seen is that figured on Plate V, Fig. 1. The animal is at that period .93 mm. long and the antennæ measure about

.57 mm., the antennules .32 mm. The form is that of a nauplius toward the end of its first phase. The antennules are much like those of males of *Moina*, being curved abruptly near the middle. They are clothed with a spiny larval integument, which disappears in the next stage. The sensory ganglia in the end and the connecting nerves are present; of the latter there seem to be two bundles having a different course. The larval eye in the middle of the head is distinct and has two lenses, or, rather, crystalline bodies.

The antennæ are of the form usual to larvæ of this family, the rami being unequal, the shorter being very indistinctly two-jointed, the longer eighteen-jointed. Near the base a small prominence bears long spines, later to serve a temporary purpose in bringing food to the mouth. The mandiblar palp is indistinctly 6-jointed, the inner ramus of this limb, or mandible proper, has a single spine.

The thoracic segments are already indicated and rudimentary limbs lie under the larval skin. The abdomen bears two styles, and has a set of muscles adapted to produce anal respiration in the rectum. The stomach is simple and glandular. Although no heart could be distinguished, blood corpuscles crowd the antennæ and other parts of the body, (see figure 4.) Rudiments of the compound eyes are seen on the sides of the head where pigment is collected.

In the next stage the animal may be .98 mm. long (Fig. 2.) and several changes appear. A well marked scutum covers the mandiblar and maxillary segments. The antennules have lost their spiny covering and the proportions of the antennæ have changed. At the base of the antennæ certain organs develop, which present great resemblances to the branchial sacs of the other feet, but which become the shell-glands of the adult. This is parallel to the like origin of these organs in copepods, as we have demonstrated in Diaptomus. In *Limnetes* it was impossible to follow the development of the shell-gland. (See figure 6, *o*, shell gland; *M*, mouth; *L*, labrum; *Md*, mandible; *Mx*, maxilla; *Mx* 2, second maxilla.) The brain lobes or supra-œsophagal ganglia resemble those organs in cladocera, the optic-lobes being apparently hollow, however. The posterior part of the body is now considerably elongated. The segments of the thorax seem to be all differentiated at once and the segmentation is obscured by a false segmenting of the posterior part of that region or the apparent absence of segments. The region about the rectum is open and crossed by the muscles giving it motion. It frequently seemed to me that this chamber was that in which the blood-corpuscles (or, better, lymph-cells) were formed. The rectum is covered with irregular masses of cells of varying size, and I more than once thought to have observed their change to lymph-cells. It was impossible, unfortunately, in the time allotted to observe the development of the circulatory system, but it would seem that the heart differentiates from the connective tissues between the stomach and the scutum.

(Fig. 3 illustrates not only the formation of the posterior appendicular segments, but the rectal sinus with its muscles and lymph-cells. A simple valvular apparatus separates the rectum from the anterior part of the digestive tract.)

The next stage is illustrated on Plate VI, Fig. 1. A change in proportion and in size is all that requires notice. Figures 3–6, illustrate the growth of the appendages. Fig. 3 is the first foot of the right side of an individual over 1.5 mm. long. Fig. 4 is the same of a younger individual of which Fig. 5 is the sixth and Fig. 6, the ninth foot. Fig. 7 shows how the matrices of the caudal spines are developed from enlarged cells as are the corresponding parts in Daphnia.

Fig 2, of Plate VII, illustrates the general characters of the animal when about 2 mm. long. The maxilla have become larger and the feet begin to assume their definitive form.

Fig. 3 shows the growth of the caudal stylets and the character of the valve at the opening of the anus, as well as the prolonged matrix at the setæ. Fig. 4 illustrates the differentiation of the optic lobes and of the anterior part of the stomach. The heart is by this time well formed and whatever part the rectal cells may have played in originating lymph-cells, is lost. The liver lobes grow out from the stomach and the labrum becomes reduced. The antennæ now undergo a rapid and remarkable transformation. In the male the shorter ramus becomes atrophied as shown in Fig. 10, and from the base an epipodal body is formed just as in the case of the feet. At first this pouch resembles homologous organs in the feet, but soon it alters and becomes greatly modified. In the female the change is similar, save that this branchial sac fails to develop (Fig. 9.) The palpus of the mandible is likewise reduced to a mere rudiment (Fig. 8.)

The sexual organs of the female appear as lobed glands (Fig. 12.) The caudal stylets are of considerable size. A male, in the stage above mentioned, measures 3.5 mm. In the following stages growth is rapid. The antennæ modify rapidly.

Figs. 2 and 3, of Plate VIII, show the form of the antennæ of the female and male in this stage, the former being .78 mm., the latter .79 mm. long. In the male the palp is gone and the appendage is considerably developed, the longer ramus still showing its primitive form. Fig. 4 figures the fourth foot of a male ⅜ inches long. Fig. 5 shows the abdomen of a larger male, and Fig. 6, the stylets when they are .78 mm. in length. Fig. 1 shows the form of the head of a male some time prior to maturity, and Fig. 8 illustrates the external genital organs of one side at the same period. The testis, only part of which is shown, is a double chamber. The penis is paired and each factor is spiny. A common muscle protrudes them both by lateral pressure, while a muscle peculiar to each serves as a retractor. Fig. 7 illustrates the form of the male antenna, previous to the branching of the so-called frontal organ. As to the homologies of the "frontal organ," there is no doubt that in Chirocephalus, as stated many years ago, it is an appendage of the base of the antenna and the development shows it related in position and formation to the branchial sacs of the other limbs.

There is a curious dimorphism among these animals, as in copepods. The males, under certain circumstances, become sexually mature, while the antennæ retain an undifferentiated character. The antenna in this stage, has a short basal process and the remainder is rather short and bifid at the tip, one of the branches bearing a sharp spine. The frontal appendage is simple, coiled, and regularly crenulate in this stage. The next stage is characterized by the elongation of one of the short branches at the end of the male antennæ and the modification of the frontal organs.

EXPLANATION OF PLATES.

Plate V.

Fig. 1. Young nauplius larva of *Chirocephalus*.

Fig. 2. The same in an advanced stage.

Fig. 3. End of body of individual of same age as figure 1, showing cavity about the rectum and its muscles, the cells springing from the walls of the rectum, the blood corpuscles, the valve at the posterior end of the stomach, and the primitive segments outlined in the cellular mass.

Fig. 4. End of the longer branch of the second antennæ, with massed blood corpuscles.

Fig. 5. Mandible and palpus.

Fig. 6. Lower view of anterior part of a larva, about the size of that shown in figure 2, *oc.* nauplius eye; *A*1, antennæ; *e*, eye; *g*, upper ganglion; *g*1, optic lobe; *A* 2, swimming antennæ (base only shown); *M*, mouth opening, bordered on either side by commissures passing to the infra-œsophagal ganglion; *L*, labrum; *Md*, mandible and palp; *Mx*, first maxilla; *Mx* 2, second maxilla; *I*, *II*, *III*, *IV*, etc., feet in different stages of development.

Plate VI.

Fig. 1. *Chirocephalus* larva in an advanced stage, seen from above.
Fig. 2. *Limnetes gouldii*, early stage.
Fig. 3. First right swimming foot of *Chirocephalus* when 1.4 mm. long.
Figs. 4–6. First, sixth, and ninth feet of younger larva.
Fig. 7. Abdomen of same.

Plate VII.

Fig. 1. Larva of *Limnetes* .33 mm. long. *A*, first autennæ; *A* 2, swimming antennæ; *Md*, mandiblar palp. *e*, eye; *l*, lense; *L*, liver, budding from anterior part of stomach; *s*, sensory filament; *m*, muscles of rectum.

Fig. 2. Larva of *Chirocephalus*, from below.
Fig. 3. Caudal stylet of same.
Fig. 4. Head, showing organs of one side, *L*, liver.
Fig. 5. Muscles of swimming antennæ.

Fig. 6. Maxilla. *Fig.* 7. End of abdomen of an older individual. *Fig.* 8. Mandible and palpus (*p*) in this stage. *Fig.* 9. Antennæ of female. *Fig.* 10. Antenna of male; *p*, inner ramus; *g*, frontal organ.

Fig. 11. Part of *Limnetes* older than figure 1.
Fig. 12. First abdominal segment of female, seen from below.

Plate VIII.

Fig. 1. Head of male approaching maturity.
Fig. 2. Antenna of female, (length of antenna .78 mm.)
Fig. 3. Antenna of male of about the same age, (length of antenna .79 mm.)
Fig. 4. Fourth foot of male ⅜ inches long.
Fig. 5. Abdomen of young male.
Fig. 6. Caudal stylets of same, (.78 mm. long.)
Fig. 7. Antenna of same.

Fig. 8. Copulatory organs of one side, *m*, muscle common to the shcaths of both male organs; *p*, penis or forceps; *t*, testis.

Fig. 9. End of sensory antenna; *a*, sensory rods, enlarged.
Fig. 10. View of the surface of the basal knob on the male antenna.

Fig. 11. Larva of Lernaea when [illegible] moulting, showing withdrawal of the hypoderm and its contents from the walls of the antennules and labrum. *A*, antennules inside the sheath formed by their old covering. *L*, labrum inside its old shell, *Lr*.

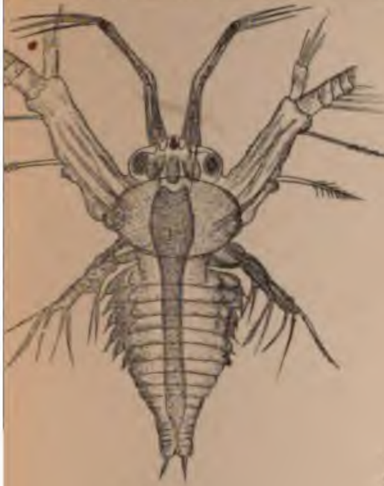
Plate V

Fig. 1. Head of [illegible] male, nearly adult.

Fig. 2. A typical foot of the same.

Fig. 3. One of the swimming feet of Lernaea.

Fig. 4. Outline of the head of Lernaea after the metamorphosis, showing relation of labrum and antennules and also the position of the beak, eye and sensory [illegible].



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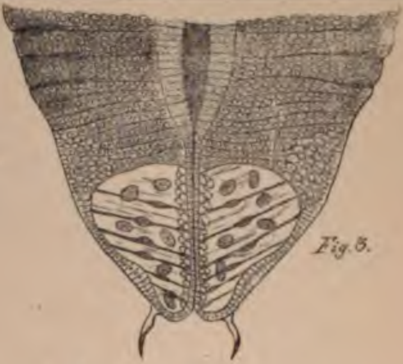

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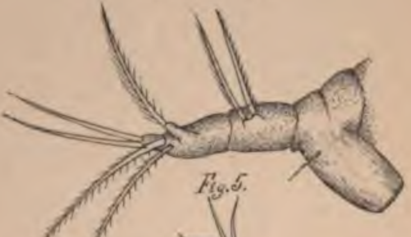

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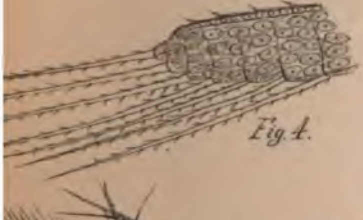

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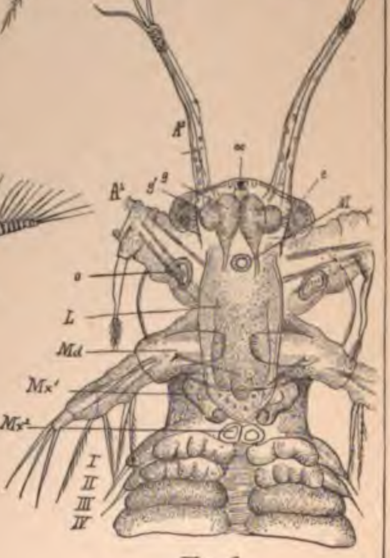

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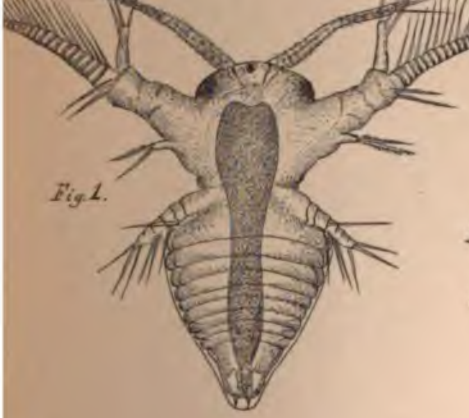

Fig. 1.

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Fig. 11. Larva of Limnetes when .5 mm. long, showing withdrawal of the hypoderm and its contents from the walls of the antennules and labrum. *A*, antennules inside the sheath formed by their old covering. *L*, labrum inside its old shell, *L*1.

Plate X.

Fig. 1. Head of *Chirocephalus*, male, nearly adult.

Fig. 2. A typical foot of the same.

Fig. 3. One of the swimming feet of *Limnetes.*

Fig. 4. Outline of the head of *Limnetes*, after the metamorphosis, showing relation of labrum and antennules and also the position of the beak, eye and sensory fleck.

PLATE V.

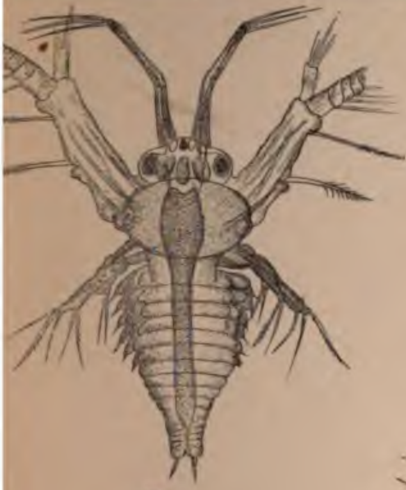
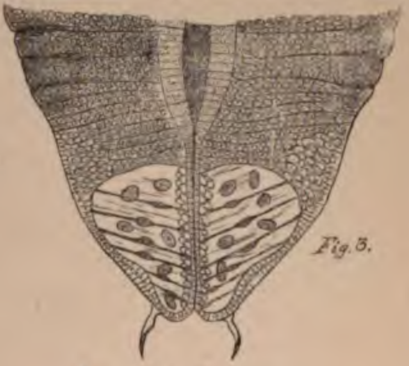


Fig. 2.



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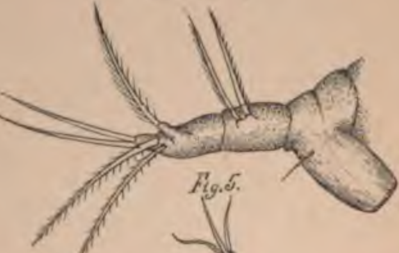

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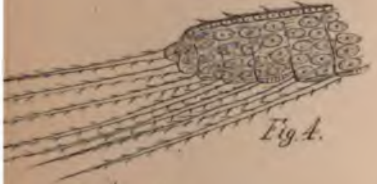
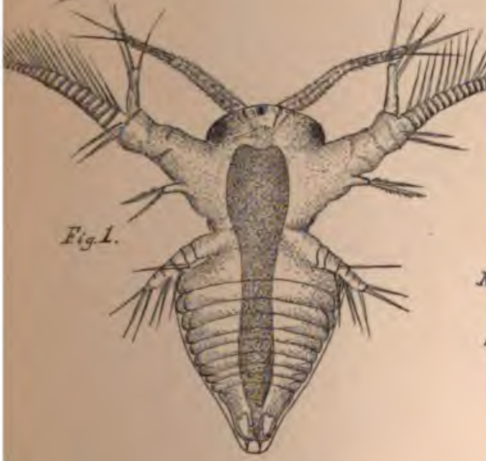


Fig. 4.



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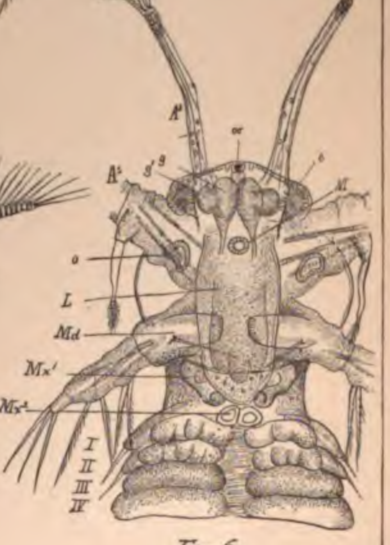

Fig. 6.

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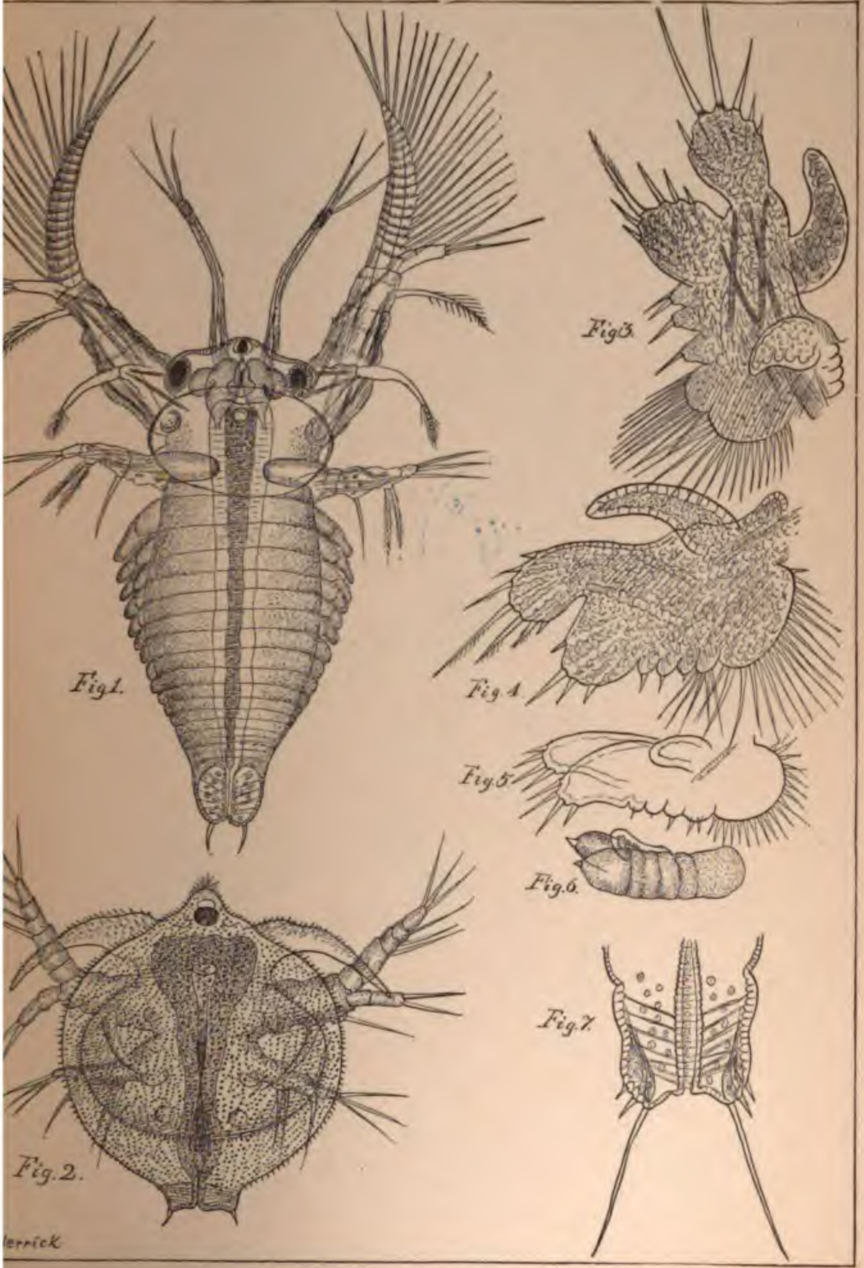

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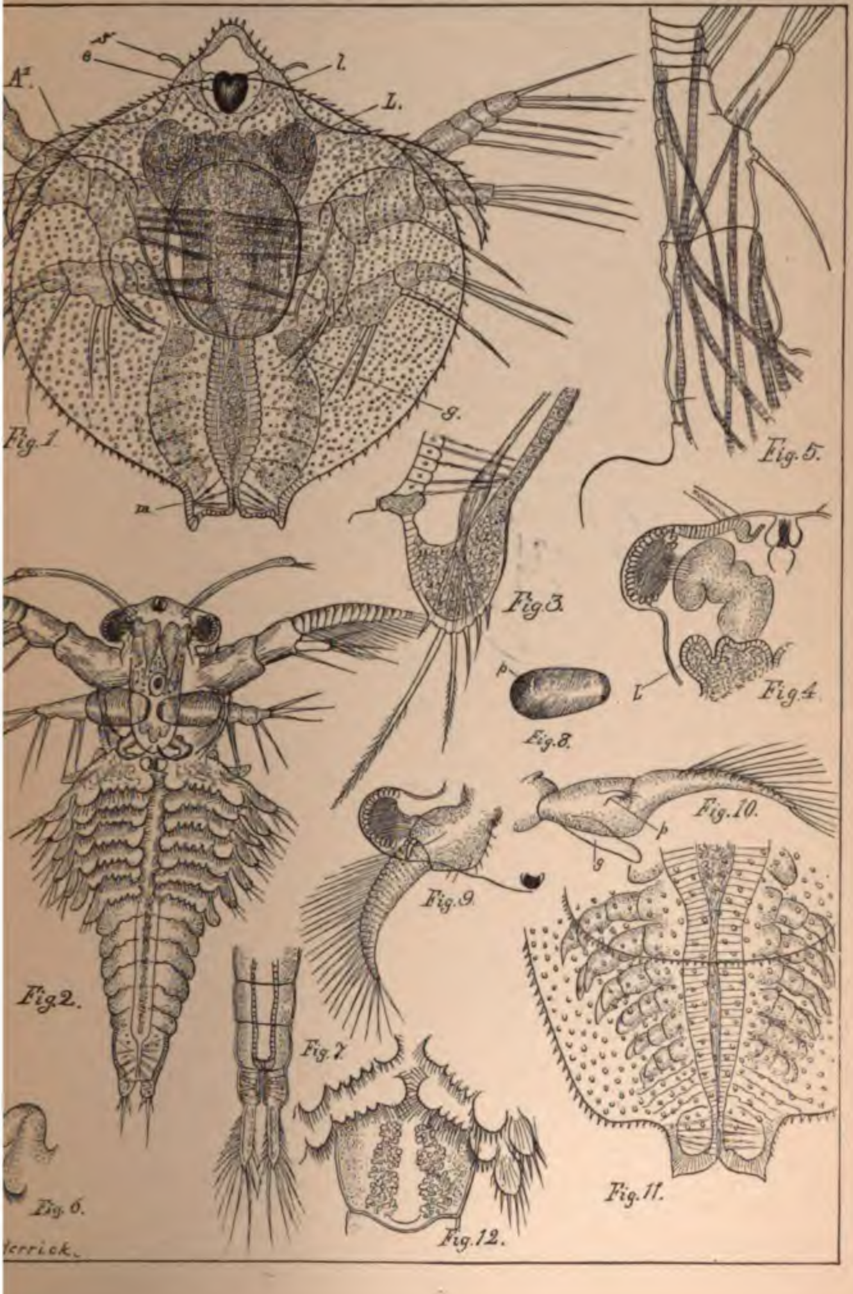
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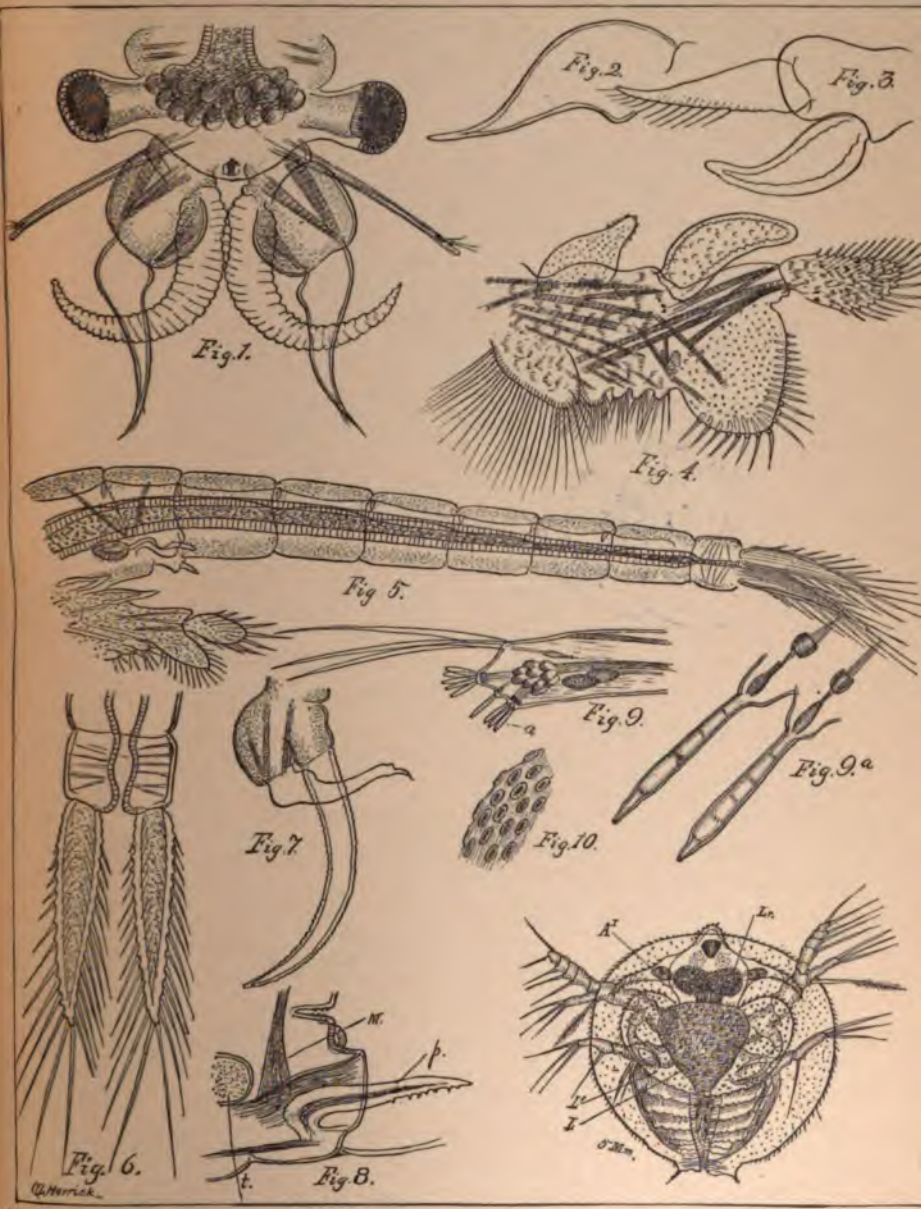
Bulletin of the Laboratories of Denison University. PLATE VII



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III.

SUPERPOSED BUDS.

Plate XII.

BY A. F. FOERSTE.

Buds are usually produced singly in the axils of leaves. When more than one bud is found in the same axil, the additional buds are *accessory* and *supernumerary*. When they are placed at the side of the one immediately in the axil, the buds are *collateral*, when placed in a line vertically above the axillary bud, the additional buds are *superposed*.

Accessory buds are not of the same age. In the case of collateral buds, the one immediately in the axil is the oldest. Among superposed buds there are two methods of development. The axillary bud first produced becomes visible, grows, and may reach some size before any additional bud is apparent. After a time another bud appears immediately above the one already produced. A third or fourth bud may appear above the one last formed. In the Tartarean honeysuckle (7) four or five buds are occasionally found arranged in such a series above the true axillary bud. This is called *direct* superposition and is of rare occurrence both among woody and herbaceous plants.

Usually, however, the axillary bud first produced reaches a considerable size before a second bud appears. This second bud is inserted beneath the one first formed. If the second grows rapidly enough, a third bud may appear beneath the second, and a fourth beneath the third. This is *inverted* superposition and is very common indeed, both in ligneous and herbaceous plants. In several species of the *Juglandaceae* and in *Gymnocladus Canadensis* (6) where the buds do not immediately follow one another but are arranged at short intervals along the internode, five or six buds are occasionally found superposed in this manner. The upper buds here betray their earlier origin by their greater size and development.

In both direct and indirect superposition the bud first formed is the largest, the best developed, and the one most likely to grow and to form a branch. If several buds produce branches, those from the later buds are successively smaller. If the largest and earliest bud dies, the next in age takes its place and produces the branch. Insects frequently cause the death of branches; early frosts may nip the tender shoot; birds, squirrels and other animals frequently feed upon the buds themselves; in all these cases the smaller, more undeveloped buds may come into play and be called upon to continue the life and growth of the plant. Superposed buds are thus a provision of nature to remedy the loss of buds or branches, however occasioned. Buds are usually formed a short time after the tissues of the leaves have become differentiated from the stem, and the ordinary scaly buds of ligneous plants can be seen in a rudimentary condition almost as soon as the leaves can be distinguished by the naked eye. By the time the leaves are fully developed the scaly buds have also reached a stage bordering on maturity, and this generally before the middle of summer. Between this time and autumn they undergo a slow change and induration which prepares them for winter. Superposed buds of the same axil originate at different times, but the bud first formed develops subsequently to the formation (differentiation) of the subtending leaf. The difference in time in the appearance of the several buds is sometimes very slight, so that they seem to originate almost simultaneously. This is true of *Gymnocladus*, in which, however, the difference in size is well marked at an early period.

Superposed buds do not appear in all the axils of a plant; it is even uncertain whether they can be found in all individuals of any single species. Nor do they always appear in equal numbers. The existence of accessory buds is a sign of vigor; the leaf-axil does more than the normal amount of work whenever it produces more than one bud. The period of greatest vigor and most rapid growth is not when the plant is small and struggling for life, but when it has reached some size and has abundant roots. Accessory buds in herbaceous plants are usually found, therefore, in the upper axils of the plant, and, if more than two buds be found in any of the axils, the greatest number will be found in the most vigorous axils. But these are not the axils last produced, because at this time of a plant's history the flowers are being formed, a period just preceeding the plant's maturity and decay, when there is not much need for accessory buds, unless it be to continue the inflorescence, as in species of *Lactuca* and *Delphinium*. Besides, at this time the rapid production of blossom and fruit seems to exhaust the vital powers of the plant. Hence, accessory buds are usually found in greatest abundance above the middle of herbaceous plants, but not at the very tips of the branches.

With ligneous plants it is different. Each year's growth may be said to repeat the life of the tree, and the twig takes the place of the entire herbaceous plant. The period of greatest vigor in an ash twig is not when the sap has begun to flow and the leaves have barely seen the sunshine, but when most of the leaves have opened out their blades and are in full operation. It is the time when the upper part of the twig is developing. In the ash, where the terminal bud is already produced in June, the leaves last formed subtend accessory buds, while those formed earlier usually subtend only the single axillary bud. In young, vigorous shoots of hickory and walnut, the axils first formed contain a single bud; those towards the middle of the branch, two buds, one of them accessory; the axils later formed, from three to four buds; and in very vigorous branches the last formed axils may contain even five buds. Many trees which usually do not form accessory buds (*Fraxinus Americana*) (1) produce large and well developed ones in all the upper axils, when the tree has been cut down and the strength of all the roots is turned to the support of a few fresh shoots growing out from the old stump.

The term *superposed* buds was introduced to explain the existing state of things in ligneous plants, where they were first studied. Here the buds are really placed one above the other along the internodes of the plant, and frequently by the lengthening of the internode during the earlier part of its growth, the buds may be considerably removed from one another and the uppermost bud may be about an inch above the lowest, as in the *Juglandaceae*. In such cases the earlier and hence upper buds, being separated while the twigs were growing most rapidly are further removed from each other, than the lower buds, which grew during the less vital period of the twig's development.*

In *Aristolochia Sipho* (8) this superposition is less evident, for here the buds are arranged at about the same height in the leaf axil, so that superposition exists only hypothetically. Although evidently superposed buds are occasionally found among herbaceous plants, in the far greater number of cases they are inserted at about the same level and superposition can only be morphologically asserted from the evident origin and development of the buds. Ligneous and herbaceous plants are almost directly opposed to one another as to the character of their superposition.

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*The separation of superposed buds, caused by the varying growth of the internodes, was noted several years ago by Mr. W. B. Werthner, who first called my attention to it. A. F. F.

Again, while in ligneous plants the superposed buds are usually found during their first season as buds, in herbaceous plants one or more buds are immediately developed into branches. Since the aerial portion of herbs in our climate is destined to decay at the approach of autumn, and sometimes even before that season arrives, buds do not long remain in a rudimentary and inactive state, but grow rapidly and form branches and flowers. The first formed bud in an herb is therefore unusually a well developed branch before the second bud in the same axil becomes visible to any but the careful observer. In some plants at this period the petiole of the subtending leaf must be carefully removed and the lower part of the developed branch closely examined in order to find the flattened bud lying closely against it. Some of the small buds later in the season turn into branches and even bear flowers, but most of them will never develop unless some accident should befall the branch already formed.

Whenever the phyllotaxy of the branch bearing superposed buds is that of decussating pairs of leaves, the lowest pair of bracts or leaves of each axillary member is always placed transversely to the stem and its subtending leaf. The lowest pair of leaves or bracts are therefore similarly inserted in all members found in the same axil. In members which belong to plants having a spiral arrangement of leaves, the lowest bract or leaf in all specimens examined was placed towards the left or right of the subtending leaf, *i. e.* transversely, but not always on the same side. Members of the same axil may have an insertion which places the first bract or leaf always on the same side of the stem, or they may be regularly opposed to one another, or there may be no definite arrangement whatever in this respect. The same thing may be said about corresponding members of different axils.

A form of superposition occurs in some herbaceous plants which seems to occupy a middle ground between superposed and collateral buds. In *Thalictrum dioicum*, for instance, the oldest bud or branch is nearly in the axil of the subtending leaf, then by means of inverted superposition follow three or four other buds or branches, not in a straight line, but placed alternately towards the right and left of such a line. The insertion, therefore, is similar to the arrangement of the uniparous scorpioid cyme. But, aside of mere appearances, there is no reason for considering them as anything but cases of superposition in which the different members of the same axil have alternately been thrown towards opposite sides. It is worthy of notice that this form of superposition is common among certain species of *Leguminosae* (*Medicago*), where the ordinary forms of superposition are also abundant both among herbaceous and ligneous plants.

Another form of superposition is very common in species of *Solanaceae*, where the main axis ends in a flower or inflorescence, which is cast to one side by the first formed axillary bud. This bud grows into a branch and continues the main axis, taking an erect position and seeming to be its direct continuation. The leaf which subtends this branch usually contains a bud which is morphologically the second-formed bud of the axil. Eichler figures in his "Bluethendiagramme" two of these accessory buds in the leaf axils of *Atropa Belladona*.

And, finally, since flowers, thorns, tendrils, and other organs are frequently the morphological equivalents of buds, they will often be mentioned in speaking of superposed buds.

In the following pages an enumeration will be made of such plants as will illustrate the general remarks made above, and any details not hitherto mentioned will be made under the particular species when cited. In these notes most attention will be paid to herbaceous plants, since less attention has been given to these, and they present some variations not noted in ligneous plants.

I. INVERTED SUPERPOSITION.

A. Of Leaf-buds and Branches.

1. Buds.—The superposition of buds, none of which have developed into branches, occurs chiefly among ligneous plants. *Fraxinus sambucifolia*, *F. viridis*, and vigorous specimens of *F. Americana* (1) have two buds in the same axil, placed close together, the lower about half the size of the upper. *Cercis Canadensis* shows two or three, the lowest of these often minute and somewhat covered by the petiole scar. *Ptelea trifoliata* (14) has also two superposed buds. In this case they are sunk into the wood and almost inclosed by the crescent- or almost V-shaped petiole-scar, so as not to be evident. *Carya*

alba (2), *C. sulcata*, *C. tomentosa* and *C. porcina*, all have the upper one of the two superposed buds so excessively developed, that the lower remains quite insignificant, often obsolete. *C. microcarpa* and *Juglans regia* have the lower buds of larger size. *Robinia Pseudacacia* has two superposed buds, both of which often develop, but the upper one outgrows the other. In this species the buds are formed beneath the surface of the petiole scar, so as to be invisible until growth begins in spring. Sometimes three buds in one row are seen bursting through the scar which has encased them all winter. *Menispermum Canadense* (17) has also two or three buds covered by the circular petiole scar, through which they burst in spring. Two of three buds often develop into branches. *Gymnocladus Canadensis* (6), which has buds enclosed by circular pit-holes in the bark, frequently presents four or five of these to one axil, the lowest being reduced to a mere dot. The upper two are always quite a distance apart—the lower ones less so. *Sambucus*, which is usually credited with the existence of buds inversely superposed, presents a poor case in *S. Canadensis*, in which the lower buds seem to develop from the upper, and not to be independent of it.

Various species of *Rubus* also show superposed buds having the general aspect of those of *Sambucus Canadensis*. In some species which usually produce three or more buds in the same axil, the uppermost bud is greatly developed and often supported by a basal internode one-eighth to one-half an inch in length. *Carya olivaeformis* (3) has two or three buds, the upper two well developed and some distance apart. The support of the upper is small, often obsolete. *C. amara*, with two or three buds placed closer together, has a support for the upper bud, often one-third of an inch long. In *Ptero-carya Caucasica* (15,) we find the extreme in length of the support–one-half to three-fourths of an inch. Three buds are normally produced in the same axil. *Liriodendron Tulipifera* has three buds close together, the upper with a support often half an inch long. These species offer a sort of transition to those in which the upper bud develops immediately into a branch.

The only case among herbs, known to me, which would properly fall under this class, is that of *Dicentra Cucullaria* (9). The grains clustered about the roots of this plant are known to be either the bases of aborted leaves, or the true bases of the leaves themselves. Both kinds of grains, when sufficiently developed, will show, on examination, a narrow slit along their upper surface. In this are found one or two buds, of which the one nearest the stem is the oldest and largest. They form an interesting means of comparison with the specimens already noted. Like these, the buds are destined to outlive the winter and begin fresh growth with the opening spring.

2. BUDS AND BRANCHES.—Species in which the uppermost superposed bud immediately develops into a branch, while lower ones remain for a longer or shorter period in the bud state, are rare among ligneous plants, while among herbs they comprise almost all known cases. In *Cornus stolonifera* (4), a shrub or small tree with two buds to the axil, the upper may develop into a branch some inches long before the season closes, or it may remain only a bud. In either case the lower bud remains small.

The first formed bud in herbs is usually a well developed branch before the second becomes visible. The petiole must often be carefully removed and the lower part of the developed branch closely examined in order to find the flattened bud lying closely against it. This in the month of July is true of *Barbarea vulgaris*, *Sisymbrium officinale*, *Oenothera fruticosa*, *Nesaea verticillata*, *Ambrosia artemisiaefolia*, *Scrophularia nodosa*, *Mimulus ringens*, *Gerardia purpurea*, *Ruellia ciliosa*, *Verbena stricta* (12), *Verbena urticifolia*, *Phryma leptostachya*, *Lycopus sinuatus*, *Teucrium Canadense*, *Chenopodium album* and many others.

Some of these smaller buds later in the season turn into branches. Even in July *Ambrosia trifida* has most of its upper axils filled with two well developed branches. In *Lactuca Canadensis* the younger branch already bears flower buds; the older branch is in blossom. *Brassica nigra* has the flowers of the older branch turned into seed, while the younger one in the same axil is flowering. In *Lysimachia ciliata*, the younger branches are partly in bud, partly in flower.

As examples of plants bearing more than two buds in the same axil, may be mentioned *Chelidonium majus* (10), which occasionally has three such buds, and *Thalictrum dioicum*, which has four or five. In *Ch. majus*, the base of the leaf and node swells and forms a *pulvinus* or cushion, extending horizontally from the stem, and supporting the buds and branches. Since these are borne on the same horizontal plane the term superposed is correct only theoretically. *T. dioicum* will be described later.

B. Of Inflorescences and Flowers.

1. INFLORESCENCES.—*Lippia lanceolata.*—A peduncle, bearing a head of flowers, is superposed to a tiny bud, which, however, does not always appear. *Dianthera Americana* presents the same features. *Delphinium consolida.*—Both the flowers composing the terminal racemes and the upper branches may be found late in the season superposed to axillary buds. The buds found along the lower parts of the racemes, and most of those in the leaf axils generally develop and flower before the season closes. *Lythrum alatum.*—Flowers said by Gray (Man. 183) to be solitary in the axils of the upper leaves. Occasionally, however, they are arranged in cymes of two or three flowers each. In this case two cymes of an equal number of flowers may be superposed to one another; or the lower cyme may be reduced to two or even one flower; single flowers are also found superposed to one another. The place of the lowest flower may even be supplied by a leaf branch which then grows vigorously and bears flowers in its turn—thus a small flower may be seen superposed to a vigorous branch. Branches in this situation occur irregularly along the flower-bearing axes of vigorous plants. *Chelidonium majus* (10).—The main stem here frequently terminates in an umbel of flowers. The bud first produced also develops into an umbel. The next bud may develop into a leafy branch and throw the two umbels to one side and place itself in the continuation of the stem. The last bud, if formed, usually remains small. *Cassia Chamaecrista.*—The raceme of flowers is found at some distance, sometimes half an inch, above the axil. Within the axil is frequently found a branch which may grow and give rise to flowers in its turn. *Penthorum sedoides.*—The lower flowering branches are found in the axils of leaves, but become more and more raised above the axils by adnation to the stem as we approach the top of the plants. The uppermost branches, bearing the immediate inflorescence, all become adnate to the stem, thus forming a single compound inflorescence, the lower members of which are raised far above the subtending leaves, while the upper members may be referred to the axils of some of the tiny bracts scattered about the common peduncle, formed by the union of the flowering branches. Some of the last members of a large inflorescence can not be referred to the axils of either leaves or bracts with certainty. Immediately in the axils of the leaves, whether containing branches in the very axil or removed to a position above it by adnation, may be found a tiny bud,

which never, or at least rarely, develops into a branch. *Lindera Benzoin* (5).—This shrub may have in the same axil either two ordinary leaf-buds, or a leaf-bud and a tiny branch, or two tiny branches. These branches bear a terminal leaf-bud and one or two axillary flower buds just beneath it, subtended by bracts. *Juglans cinerea* and *J. nigra* produce from two to five buds in the same axil, which in the latter species are found closer together. In older trees one or more of these buds develop into the sterile catkins.

2. FLOWERS.—Since flowers are also the morphological representatives of branches, and hence of ordinary leaf-buds, a few species may be mentioned in this connection.

A sort of intermediate condition between flowering branches and flowers are those in which the flower peduncle bears a single leaf-like bract. *Lilium bulbiferum*, to be described later, is such a case. *Aristolochia Sipho* (8) is another. The latter has three or four superposed buds, of which the upper are the strongest. They are during the first season almost enclosed by the base of the petiole. The upper bud, sometimes the two upper buds, are leaf-buds, the remainder being flower-buds. All develop during the following season. The cases of *Delphinium* and *Lythrum* have already been described. *Lindera Benzoin* sometimes belongs here. *Lysimachia nummularia* frequently shows small buds just beneath the flower peduncles, which, I suppose, occasionally develop into leaf-branches. Various foreign species of *Loranthaceae* are known to contain one or more vertical rows of superposed flowers in the axil of the same bract. The flowers, however, are all sessile in these cases.

C. *Other Morphological Equivalents of Branches or Buds.*

1. THORNS.—*Gleditschia triacanthos* also bears a superposed bud, developed in this case into a many spined branch or thorn. Each spine of this thorn is subtended by a small scale, representing a leaf. Below in the axil of the subtending leaf may be found three or more buds, also in superposition. The thorn is usually found removed quite a distance from the leaf axil to which it belongs. The place of the scale in this thorn is often supplied by the leaves themselves.

2. BULBLETS.—*Lilium bulbiferum*.—A peduncle, bearing a leafy bract and a flower, is here superposed to a bulblet immediately in the leaf axil. This bulb may have accessory collateral bulblets on either side.

D. Irregular Superposition.

I. SYMPODIAL GROWTH.—Those species of plants, especially common among *Solanaceae*, in which an axillary branch continues the stem of the plant while another bud is formed in the axil of its subtending leaf, have often been made the subject of special investigation and can be studied in books especially devoted to this subject. The *Vitaceac* among ligneous plants present cases in some respects similar to these. They are all caused by *sympodial* growth.

II. ZIG-ZAG SUPERPOSITION.—Scarcely any other term will express the arrangement of the superposed branches and buds of the plants in question. In *Thalictrum dioicum* the branches will be found thrown alternately towards the right and left of a true median line. The superposed buds, both leaf- and flower-buds, of *Aristolochia Clematitis* will be found arranged in a similar manner. *Atriplex patula* shows the same manner of arrangement. (See Eichler, Bluethendiagramme, II., pp. 83, 533 and 159.) Various species of *Leguminosae* present the same or similar features. In their case the interest is so much greater, on account of the ordinary forms of superposition common to both the ligneous and herbaceous plants of this order. Thus, for example, in *Melilotus alba* the buds are thrown alternately towards the right or left of a true median line, and even where only two buds are found and where crowding is not so evident the same features still present themselves. In closely related species of *Trifolium*, however, the superposition is of the ordinary kind.

II. DIRECT SUPERPOSITION.

Lonicera Tartarica (7). Two to five buds are here superposed. The one directly in the axil is formed first, and those above at successively later periods. The lowest bud is the strongest and generally produces the branch, but occasionally several of them develop. Among flowering branches, the lowest buds produce the flowers, or flower-clusters. *Coreopsis tinctoria* (16).—The upper leaf axils contain a flowering branch, superposed to which is a small bud which later in the season produces two or three leaves and a flower. *C. tripteris* has larger and more developed superposed buds, the upper of which bears leaves and two or three flowers. The superposed branch is inserted, as in the first, directly between the axillary branch and the stem. *Passiflora lutea.*—Immediately in the axil is a tendril which represents the first bud. At either side of the tendril, representing its branches, is a flower. Above the tendril is found a bud, the undeveloped superposed branch.

(In a curious specimen of *Ulmus fulva* (11), found near Dayton, there were two leaf scars, the places of attachment of two leaves, which supported but one bud, the normal arrangement of the remainder of the branch being otherwise preserved.)

EXPLANATION OF PLATES.

Plate XII.

SUPERPOSED BUDS IN—

Fig. 1. *Fraxinus Americana, L.*, from a one year old shoot growing out of the stump of a tree cut down during the previous year.

Fig. 2. *Carya alba, Nutt.*, the tip of a branch.

Fig. 3. *Carya olivaeformis, Nutt.*, section of a node taken from the upper part of a twig.

Fig. 4. *Cornus stolonifera, Michx.*, A, section of a node showing the contents of only one leaf axil. Twig collected in autumn, showing one of the superposed buds partly developed. B, diagram of buds as they appear in less vigorous axils.

Fig. 5. *Lindera Benzoin, Meisn.*, superposed branches composed in each case of a terminal leaf-bud, and two lateral flower-buds.

Fig. 6. *Gymnocladus Canadensis, Lam.*, buds enclosed in pit-holes.

Fig. 7. *Lonicera Tartarica, L.*

Fig. 8. *Aristolochia Sipho, L'Her.*, a regular leaf-branch represents the first formed bud of last year; the flower, the second bud. B, diagramatic section, showing the buds still undeveloped.

Fig. 9. *Dicentra Cucullaria, D C.*, A, section of a grain. B, slightly enlarged portion of the same, both sections magnified.

Fig. 10. *Chelidonium majus, L.*, A, the main axis is here turned into an umbel of flowers, the first developed bud is in the same case, the second bud is a leaf-branch, the third is still in the bud state. B and C, diagrams showing the relative insertion of branches and leaves. D, a case of superposition with two of the buds developed into leaf-branches.

Fig. 11. (*Ulmus fulva, Michx., a freak of nature, two leaves subtending one bud.*)

Fig. 12. By mistake marked 2 in the lower part of the plate. *Verbena stricta, Vent.*

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Fig. 9. *Dicentra Cucullaria, D C.*, A, section of a grain. B, slightly [illegible] section of the same, both sections magnified.

Fig. 10. *Chelidonium majus, L.*, A, the main axis is here turned into [illegible] developed bud is in the same case, the second bud [illegible] in the bud state. B and C, diagrams showing the [illegible] and leaves. D, a case of superposition with two [illegible] leaf-branches.

Fig. 11. [illegible] *Michx.*, *a freak of nature, two leaves* [illegible]

Fig. 12. [illegible] marked 2 in the lower part of the plate. [illegible]

Fig. 13. *Ambrosia artemisiaefolia, L.*, the first bud has here developed into a leaf-branch; the second, into an inflorescence.

Fig. 14. *Ptelea trifoliata, L.*, A, a case of "Uebergiphelung". B, enlarged section of a node of the same twig.

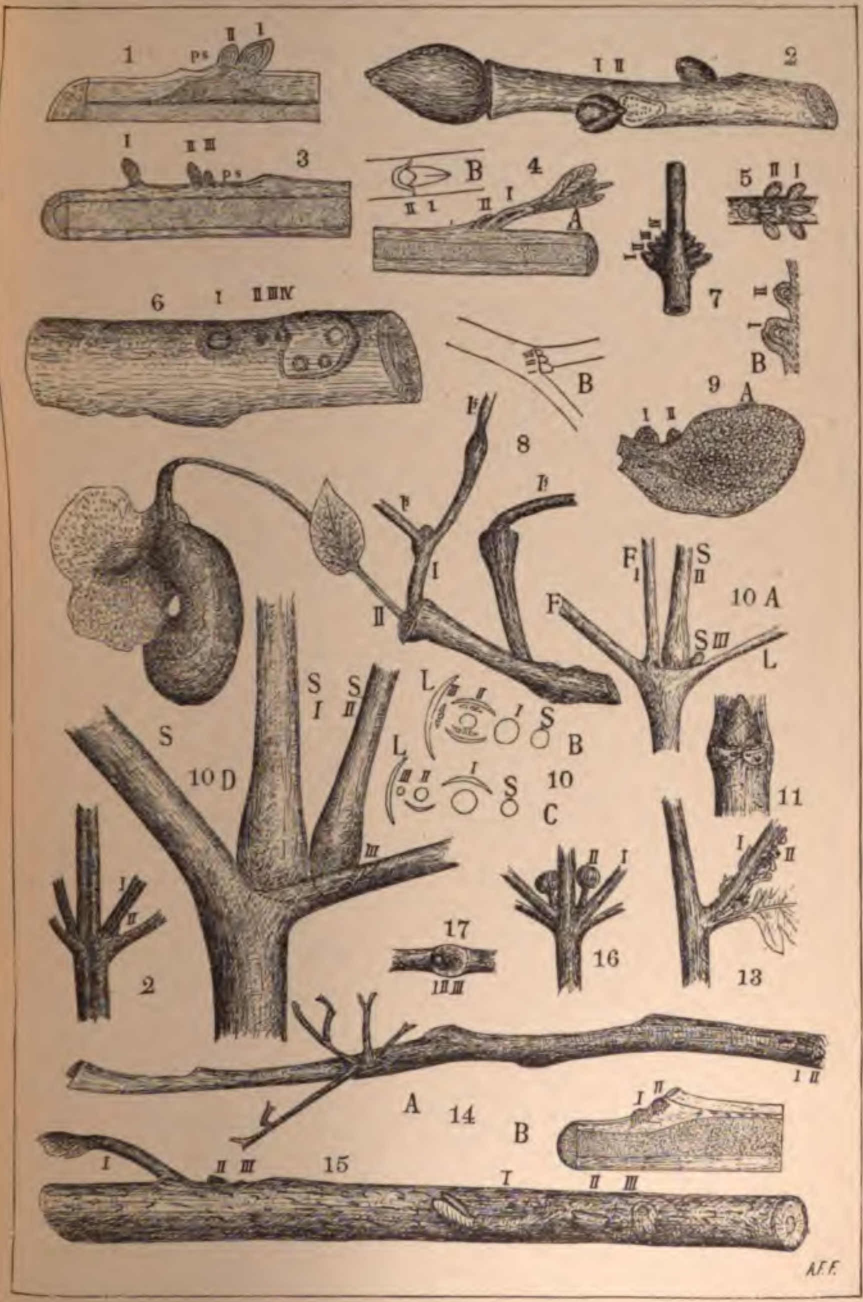
Fig. 15. *Ptero-carya Caucasica.*

Fig. 16. *Coreopsis tinctoria, Nutt.*, the first bud developed into a flowering branch; the second, into a flower bud.

Fig. 17. *Menispermum Canadense, L.*, three buds bursting through the petiole scar.

I, II, III, &c., the first, second, third, &c. oldest buds or their equivalents; ps, the petiole scar; lf, the petioles of leaves; S, stems of leaf-branches; F, stems of flowering branches or peduncles of inflorescences. Figures are cited in the text by their numbers.

PLATE XII.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IV.

MUD-INHABITING CRUSTACEA.

Plate IX.

Among the curiosities of pond life are certain minute crustaceans which spend their entire life in the soft debris and mud forming the superficial deposit at the bottom. The *Canthocamptus* among copepods is commonly found in such situations, but this is less surprising than that members of the cladocera, or shelled entomostraca, with their delicate organization and frail structure should have become adapted to such a life. In many marine crustaceans (copepoda) the accomodation to such a reclusive life is manifested in the retrograde development of many of the organs—eyes, even, being absent in several cases. The present paper is concerned only with a few cladocera, which are peculiar to America or rare both here and elsewhere, and which exhibit curious and instructive modifications as a result of such a habitat. The reader who wishes to familiarize himself with the systematic classification of the group would do well to consult *Die Cladoceren Boehmens*, by Hellich, Birge's *Notes on Cladocera*, and the writer's *Final Report on Crustacea of Minnesota*, while, for a thorough study of the physiology, Weisman's *Beitraege zur Naturgeschichte der Daphnoiden*, is necessary. A special paper on the limicole or mud-loving cladocera was published in the Zeitschrift fuer Wissenchaftliche Zoologie, in 1878, by Dr. Wm. Kurz, and entitled *Ueber limicole cladoceren.* Reference will be frequently made to this paper and this must be understood in all cases of reference to Kurz, unless otherwise specified. These mud-dwellers are happily called "*schmutz-peterchen*" cladocera, *i. e.* "Smut-Johnny," or chimney-sweep water fleas. In America the following species are pre-eminently worthy of the name: *Monospilus tenuirostris*, *Leydigia quadrangularis*, *Alona sanguinea*, *Alona quadrangula*, *Pleuroxus procurvus*, and several other members of the genera Alona and Pleuroxus. The typical cladocera are graceful in movements and slender in form. Very generally they are more or less boat-shaped and the polished shell is modeled like a clipper, the head-shield forming the prow, while, in a few cases of the best swimmers, (as *Camptocercus*, *Acroperus*, and *Alonopsis*) there is developed a sharp ridge upon the back which bears an unmistakable resemblance to the keel of a boat and, since the animals swim upon the back, may not impossibly serve a similar purpose.

In the mud-loving species, on the contrary, the body is clumsy and approaches the spheroid in form, the antennæ, which normally are oar-like and long, bearing fringed setæ, are short and are armed with claw-like spines and smooth setæ. The post-abdomen or tail, which in the natatory species is reduced in size and subordinated in function, is here enlarged and armed with numerous and considerable spines. The front of the head is either reduced and pointed, or, if there be a long beak, it is turned up out of the way. The meaning of all this is that the animal no longer swims on its back, but creeps humbly and prone and requires the efforts of post-abdomen and antennæ, as pushing poles to make its way through the debris in seach of food. The effect of this manner of life is seen in several other ways, as in the structure of the shell itself. In several of our species the shell, which is renewed periodically, is not, as in other cladocera, moulted, but remains as a sort of outgrown overcoat, after the new shell has become perfected.

The result of this is what might be expected from the sluggish nature of the animal, the supply of clothing thus accumulated becomes so onerous a burden that it no longer could swim if it desired and is thus fettered to the life it early chose. While this is true of a few only, yet in all the limicole cladocera the cuticle becomes indurated and it follows that respiration, which normally takes place from the entire surface of the body, becomes restricted to those membranes in contact with the water within the valves of the shell. As a partial offset to this disadvantage, the strictly respiratory appendages on the feet are enlarged more than in most groups. The sensory organs are modified in several ways. Kurz calls attention to the fact that the antennules are movably joined to the body in the limicole cladocera; they are also, as a rule, rather large and well endowed with sensory apparatus. The compound eye is small and, in one species, as we shall see, fails to develop at all.

MONOSPILUS DISPAR, Sars. is the most remarkable of all filth-dwellers. This animal may probably lay claim to be called the rarest of the family and has been seen but few times. First described and figured by Fischer, from Russia, it next turns up in Scandinavia, where Sars gives a full Latin description. Norman and Brady find it in England, and Mueller in Denmark, and, finally, Hellich records it in Bohemia. It was also reported from Minnesota, by the writer, in 1884.

Unlike most other limicole cladocera, the body is narrow and high, rather than globose, the head is much depressed and terminates in a slender rounded beak, like the bill of a duck. The fornices or free margins of the head-shield are narrow and flaring. The shell of an old individual is a curious pile of overlapping valves, and is ornamented with concentric series of depressions. The lower margin is nearly straight and bears a row of long curved teeth (not free spines), back of which are two small teeth. The antennæ are short and the antennules rather slender. In this respect our specimen seemed to disagree with the figure given by Hellich. The labrum is of large size and is produced into an acute appendage below, as in most Lynceids. The compound eye is quite absent, but its function is subserved by the larval organ, a quadrate and rather large fleck at the base of the antennules. The intestine is coiled once and one-half times and opens in about the middle of the flat, pentagonal post-abdomen. The latter bears straight terminal claws, each with a single basal spine, a series of rather small triangular teeth, posteriorly, and irregular areas of fine spines upon the sides. The male is not known and many points of interest remain to be made out.

The two species of *Leydigia*, both of which occur in America, are familiar enough and are sufficiently well described to render a repetition of the description needless. It is otherwise with the only species of *Ilyocriptus* yet found in America.

ILYOCRYPTUS SETIFER, Herrick.—The description given in my "Final Report, etc.," is very brief and no comparisons were there instituted with the *I. agilis* of Kurz which is its nearest ally in Europe. The paper by Kurz referred to gives detailed descriptions of the three European species accompanied by elegant plates. We are able, therefore, to draw up the following distinctive diagnosis of the species, hoping thereby and by means of the figures to show the relations of the four species at present known. It is almost certain that we have more than one species in America and the careful description of the known form may make the detection of others easier.

The size varies greatly, a full grown female with eggs in the brood cavity is nearly .90 mm. long and .70 high, while a smaller female measures .65 mm. long by .44 high. The form of the shell is nearest like that of *I. acutifrons*, the heighth being less than in *I. sordidus*, and the angle between the ventral and posterior margins less than in *I. agilis*. The entire length of the post-abdomen in the large female is .56 mm. measured to the base of the caudal stylets, of which length .168 mm. pertains to the claws. The width of the post-abdomen is but .14 mm. Thus it is evident that the proportions of the post-abdomen differ greatly from any of the other species, it being very long and narrow. The terminal claws are exactly as in *I. agilis*, having two small basal spines and a few sharp serrations near the apex, anteriorly. Near the base of the claw is a cluster of small spines of two sizes, then begins a series of about sixteen lateral teeth averaging .02 mm. in length and extending to the sides of the anus. Above this point the contour of the margin is convex and is ornamented with nine spines twice as long as the preceeding. Then follow the prominences which bear the long and simple caudal setæ. Besides the above mentioned spines there are four spines on either side upon the lower posterior angle of the post-abdomen which are four times as long as those of the previously mentioned continuous series (*i. e.* .08 mm.) Above, the abdomen is hirsute or thorny as in *I. agilis*, and the process for closing the brood sac is similar. It will be seen that the post-abdomen differs in armature as much as in form from other species. From *I. sordidus* it differs in the following points :—the claws are not pectinate behind but are serrate in front, the anal opening is higher and the details of the spines vary ; from *I. acutifrons* it differs in that the claws are not pectinate, neither is there a spine in front of the claws, and the anus is not terminal; from *I. agilis* it differs, in that the shape is different, there are fewer enlarged spines, and the shape of the nine spines above the anus is different. The head is convex, resembling *I. sordidus* most nearly, but the antennules are much longer and more slender than in any other known species. They are .17 long and about .016 mm. wide, while the longest seta is .084 long. The antennæ are almost exactly as in *I. sordidus*. The labrum has the usual shape, as have the jaws and other appendages. The margins of the shell are ornamented with spines simply pectinate or barbed, as in *I. agilis*. In *I. sordidus* these spines are variously branched and in that form alone of the European species, according to Kurz, is there a failure to perfect the moult; in our species, which has simply pectinate setæ, the old coverings are all but uniformly retained. The spines of the lower posterior margin are from .16 mm. to .20 mm. long.

Such are some of the chief peculiarities of the species, but, to make the relation between the four species of this little-known genus even clearer, if possible, the following comparative table is appended.

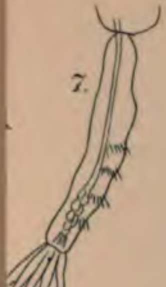
The shell moulted periodically —	*I. agilis.* *I. acutifrons.*
The shell not moulted but retained—	*I. sordidus.* *I. spinifer.*
Antenules not more than eight times as long as broad—	*I. sordidus.* *I. agilis.* *I. acutifrons.*
Antenules more than eight times as long as broad—	*I. spinifer.*
Claw of post.abdomen pectinate—	*I. sordidus.* *I. acutifrons.*
Claw of post-abdomen not pectinate—	*I. agilis.* *I. spinifer.*
A strong spine in front of claw—	*I. acutifrons.*
Fine bristles or none in front of claw	*I. sordidus.* *I. agilis.* *I. spinifer.*
Anus opening near the claws—	*I. acutifrons.*
Anus about midway of the posterior border—	*I. sordidus.* *I. agilis.* *I. spinifer.*
Marginal spines of shell much branched—	*I. sordidus.*
Marginal spines nowhere much branched—	*I. agilis.* *I. acutifrons.* *I. spinifer.*
Elongated anal spines on either side, four or five, very long—	*I. spinifer.*
Elongated anal spines more numerous—	*I. agilis.* *I. acutifrons.* *I. sordidus.*
Upper (one to three) spines of the supra-anal series modified and enlarged—	*I. acutifrons.* *I. agilis.*
Upper spines like the others—	*I. sordidus.* *I. spinifer.*

Plate IX.

Fig. 1. *Ilyocryptus spinifer*, Her., female.
Fig. 2. Post-abdomen of same.
Fig. 3. Antenule of same.
Fig. 4*A*. Jaw of *I. sordidus*.
Fig. 4. Post-abdomen of same.
Fig. 5. Post-abdomen of *I. agilis*.
Fig. 6. Head of same, antennæ being removed.
Fig. 7. Antenule of *I. sordidus*.
Fig. 8. Spines on edge of shell of same.
Fig. 9. Post-abdomen of *I. acutifrons*.
Fig. 10. *Monospilus dispar*, female.

Plate IX.

7.



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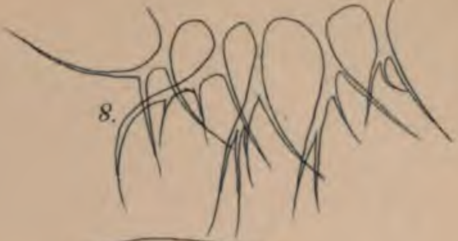

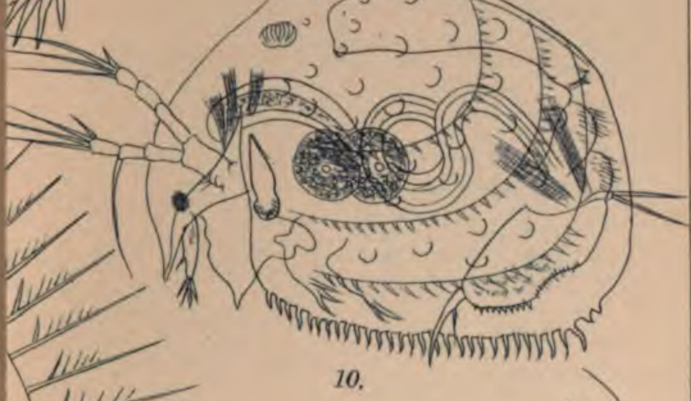

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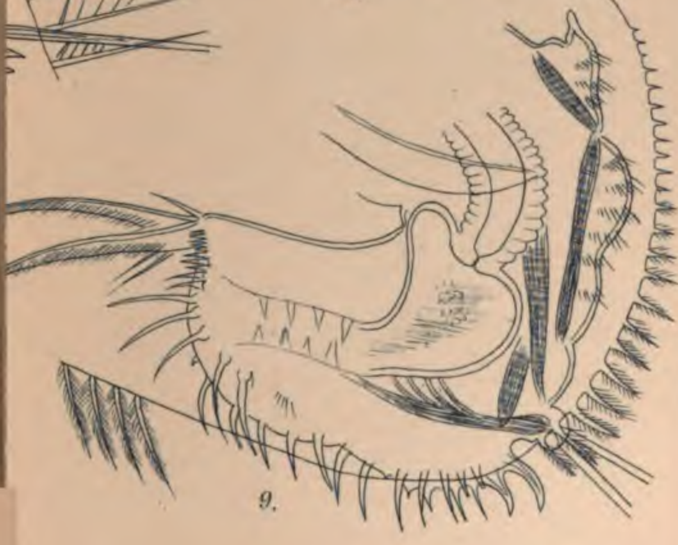

9.

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V.

NOTES ON AMERICAN ROTIFERS.

BY C. L. HERRICK.

[*Plates II—IV, and Plate X.*]

Introduction.—In the series of papers here begun, it is expected to treat the subject in somewhat the following order: First, in an introductory section, an outline of the general charácteristics will be given, then we shall proceed to a description of species without attempting to treat them in systematic order, finally, if permitted, space may be devoted to a review of the classification and a more detailed discussion of anatomy and development. The present installment attempts simply to describe a few of the common species of a number of genera.

A rotifer may be described as a worm-like, bilateral, metazoan, moving by means of a circum-oral trochal disc, and either adherent or free-swimming. Many of the animals of this group are exceedingly small and are greatly exceeded in size by certain Infusoria, and it was this circumstance, as well as a certain outward similarity in appearance, which led Ehrenberg to include both under the one head and to ascribe to Infusoria the same complicated structure he was able to make out in rotifers. Living in all fresh waters, these animals are among the most accessible objects for the microscope, yet, on account of the care necessary in their study and the scattered literature, they have been much neglected in America.

The body of all rotifers exhibits a tendency to segmentation, which is, however, mainly confined to the integument. The inner organs are but slightly affected by the jointing, except the muscular system which is, moreover, largely responsible for the number and arrangement of the segments. Very generally the body terminates posteriorly in a several-jointed abdomen or "foot," which bears two caudal stylets and contains glands which secrete a gummy fluid used by the animal in temporarily adhering to other objects. The form varies from nearly spherical or round lense-shaped to terete and extended. The cuticle is modifided in various ways, sometimes appearing like a bivalve shell and thus hightening the resemblance to certain entomostraca and explaining why older naturalists classed the rotifers under crustacea. The cuticle may be smooth or beautifully ornamented and produced into long spines or marked off into areas outlined by impressed or raised lines. The cuticle is secreted by a hypodermic layer which is often seen obviously to consist of cellular tissue. Notwithstanding the protection afforded by a chitinous shell, some species (as *Melicerta ringens*) build for themselves a tube composed of materials gathered from the water and apparently connected by a cement secreted in a gland near the mouth. Such an envelope may be compared to those swallows' nests eaten in Asia, or the case of a caddis-fly. Some of the species live in colonies, and when the colony is spherical, as in *Conochilus*, it is a veritable microcosm—a sphere of active, voracious creatures whirling through aqueous space. In only one case is it certainly known that a moult takes place, and facts seem to be unharmonizable with the theory that such a change of coats is affected.

The cilia of the trochal disc or "wheel" are arranged in the greatest variety of ways in different genera. The attempt is made to refer all these forms back to a fundamental form—*i. e.* a double circlet of cilia, the outer of which is largest and serves as locomotory, while the inner set is under the control of voluntary nerves and serves simply to bring food within the pharynx. In many cases there is really no indication of such a distribution and the cilia seem to be merely isolated clusters of hairs scattered about the oral end of the body. Several of the rotifers are parasitic and cling to the less exposed parts of the body of certain Amphipods, or on Annelides, or are endoparasitic. The muscles are often very conspicuous and, when large, show the striated structure well. The alimentary canal, maxtax, and the contractile water vessel have muscular tissue af another sort.

The nervous system is most difficult to study and little is certainly known of its structure. Usually there can be made out a considerable granular mass over the maxtax and in close proximity to the eyes, this is assumed to be the principal ganglion. From the chief or central ganglion fine nerves pass to the muscle and organs of sense.

The eyes are double or single and are sometimes supplied with a lense; they are always furnished with a dark red pigment and, very generally, rest directly upon the ganglion. There are occelli at various points in the trochal disc of some species. The sense of touch is delicate, and there is often a special tactile tentacle, or palpus with minute tactile rods. This may be reduced to a slight papilla or a pit, with sensory hairs. No other sensory organs have been discovered, although Huxley fancies that to be an octocyst, which the Germans call the "Kalk-beutel," *i. e.* the lime-sac. This is a spheroidal sac, containing irregular grains of lime. The function is unknown, but it may be simply a reserve supply to be used in preserving the rigidity of the indurated parts of the body.

The mouth is more or less ventral, while the anus is dorsal. The mouth leads by the pharynx into a roomy and expansible crop or directly into the maxtax or masticatory organ, and this is armed with chitinous appendages of the most various form, but referable to a simple type. Here there is a central anvil-like part called the ***incus*** and two lateral ***mallei*** which consist of a handle (or ***manubrium***) and a head (***uncus***) which beats upon the incus and reduces the hard parts of the food. The maxtax opens into a narrow ciliated œsophagus which, in turn, leads to the stomach proper.

The stomach is sometimes quite distinct from the succeeding parts of the system, but sometimes can only be distinguished by the large size and absorbtive character of its cells. Into the stomach is poured the secretion of a pair of glands which may be compared to the so-called salivary glands of insects or the liver and salivary glands of vertebrates. The size of the glands is dependent on the diet of the animal. In carnivorous species the glands are small, while in others they become quite conspicuous. The intestine is clothed with long cilia and opens into the cloaca or common receptacle of the reproductive, water vascular, and alimentary systems. In some species, however, the stomach is a cœcum and has no anus. Males uniformly lack the alimentary system and are short-lived creatures of love. In some cases evident messentaries support the digestive tract.

The excretory system consists of a pulsating bladder, opening into the cloaca, and two lateral vessels of various form, upon which are flagellate chambers which contribute to keep up a circulation between the cavity of the body and this vascular system.

Respiratory and circulatory organs, in the received sense, are absent, respiration taking place, as in many small entomostraca, through the body surface, and circulation is affected by the rythmical movements of the digestive tube and the ciliary action in the later vessels.

In mature females much of the body cavity is filled by the ovary and the yolk masses or eggs. The ovary is disc-shaped, botryoidal or variously contoured and in the grey substance exhibits hyaline spots containing the nucleated ovule cells. A part of the ovary temporarily secretes the yolk when the egg reaches maturity, so that the appearance of the viscera differs greatly at different times. The egg, after extrusion, is commonly carried about in a delicate external brood-sac as in copepoda.

To add here the details of the development of the egg would lead us too far. The male, as before said, has no functional digestive tract and is not only much smaller than the female, but suffers a reduction in many organs. The sensory organs are, however, well developed. The testis is spindle-shaped or oval and opens in a papilla, which also contains the opening of the water chamber or pulsating vessel. The spermatozoa are rod-like or thread-like and motile.

The Rotifera are found in fresh and salt water over the entire globe. Some species may be found in damp situations on land. They exceed even the lower crustacea in their great adaptability to changes in outward surroundings. Not only is drought not destructive to the eggs, but the animal itself endures a long period of dissication. Other notes upon the habits must find their place under the special descriptions.

Descriptive Part.—As above stated, the following descriptions are given without attempt at orderly arrangement, with the expectation of ultimately attempting a systematic review. In cases where lack of literary aids make positive identification impossible, the description alone will be given, awaiting future identification.

GENUS FLOSCULARIA, *Oken.*

The head is margined by five oval processes bearing exceedingly long setæ of excessive fineness. The mouth is central, with a funnel-form opening. There is a crop-like vestibule, separated by a partition from the pharynx, except in the centre, which is perforate, the opening being margined by several pendulous cilia. The adult is attached by a long, jointed foot, but the young is motile and possesses eyes, which are aborted after the metamorphosis.

FLOSCULARIA ORNATA, *Ehr.*

is not a rare inhabitant of the pools of Minnesota. The very full descriptions of this species, given by various authors, would seem to have exhausted the subject, but we do not even yet feel sure that the so-called species are not local or age variations. The other species are *F. appendiculata*, *F. proboscidea*, *F. complanata*, *F. longiloba*, and *F. trifolium*.

Of *Rotifer* and *Callidina* we find a number of species, but reserve the consideration of the group for another occasion.

Notommata furnishes several species which are very abundant and striking, but a large number of works are necessary for their study.

GENUS EUCHLANIS, EHR.

The lorica is oval and composed of an arched dorsal shield and a plane ventral one. The lorica in front is broad and presents a large opening for the head. The shell often has a carina above, while the dorsal shield is movable upon the ventral. The trochal disc is strongly ciliate and bears two terminal sensory organs with clumps of tactile hairs. There is a single cervical eye and the viscera are highly differentiated. The foot has four short segments and two terminal lanceolate claws.

EUCHLANIS (DILATATA) HIPPOSIDEROS, *Gosse.*

[*Plate III, Fig.* 2.]

The identification of our species with the above is made in spite of minor points of disagreement which may be looked upon as the result of faults in the descriptions or slight variations in structure. Eckstein gives the length at .45 mm., while Eyferth says .23 mm. Our species varies only between .22 and .24 mm. and is quite uniform, so far as observed. The form is oval, the lorica being excavated before and behind, as shown in the figure, although it is not often seen as clearly as drawn.

The trochal disc has two broken circlets of cilia, and on either side the head is a pit densely ciliated within. The drawing given by Eckstein shows the arrangement well. Two curious sensory organs occupy the very front of the head. The ganglion is very large and quadrate, the eye being near its anterior part and quite large. The maxtax is quadrate, showing the component parts well. The stomach is ob-pyriform and there are two accessory glands. The ovary has very large nuclei and the egg is of great size. The contractile vessel is clearly seen and all the details of the water vascular system may be made out with ease. The lateral vessels are tortuous canals, while upon them are seated beaker cells, the flask-shaped base of which connects directly, by means of a curved tube of less diameter, with the main canal. The mouth of the flask is directed downwards and has a small opening near which is the point of insertion of a long cilium which extends upward into the flask, where it is constantly in motion. There seems to be no reason to doubt that by means of these beaker-cells the vascular system is in communication with the perivisceral cavity. The foot is comparatively slender and has, aside from distinctly cross-striate muscles, two large foot glands which open in the ends of the rather long dagger-shaped claws. A pair of fine bristles springs from the dorsal surface of the last segment of the foot.

The following measurements were taken:

No. 1.	lorica	.22 mm. long.	No. 2.	.22	No. 3.	.24
	"	.14 mm. wide.		.14		.15
	foot	.06 mm. long.		.06		—
	claws	.07 mm. long.		.07		.072
	jaw capsule	.06 mm. long.		.06		.048

Found in Minnesota during the whole summer among water plants.

EUCHLANIS AMPULIFORMIS, *sp. n.*

[*Plate II, Fig.* 3.]

This species, which deviates toward *Salpina*, is smaller than the above and, in outline, is somewhat flask-shaped. The back is carinate and the flat ventral plate is excavated posteriorly with a cordate opening. The head is produced and densely hairy below. The maxtax is small, but the cervical eye is very large. The nuclei of the ovary are very conspicuous, although the egg is not as large in proportion as in the above. The foot is four-jointed and the claws are elongated and somewhat curved. The lorica is .16 mm. long, the claws .08 mm. Another individual measured .20 mm. and the claws were .12 mm. long. This species was seen but twice, June 18th, 1884, in Minnesota.

POLYARTHRAEA.

The family includes the two genera, *Triarthra* and *Polyarthra*. In both genera the foot is wanting and appendages of the sides of the body take its place. The body is not segmented except anteriorly and the form is not definite. The genus first mentioned has two lateral and a ventral appendage, while in Polyarthra the appendages are collected in groups upon the opposite sides. In both genera the egg is carried about as in *Anuræ*,

GENUS POLYARTHRA, EHR.

A single species has so far been encountered and I am able, with the works at hand, to discover no reason to doubt its identity with *P. platyptera* of Ehrenberg.

When swimming freely this animal seems to consist of two quadrilateral segments, the first, or head segment being considerable shorter than wide in outline, while the body is a third longer than wide. The trochal ciliation is slight. Two sensory organs are conspicuous upon the front of the head and the eye occupies the middle of the first segment near its posterior margin. The maxtax is very large and the stomach is short, with a tubular intestine. There are two prominences on either side of the body near the front, each bearing three lanceolate spines. The egg is very large and is perhaps half as bulky as the whole body. The contractile vessel is small and little could be seen of the lateral vessels. The length is .10 mm.; width, .08 mm.; setæ, .088 mm. long. This species seems rare and was found among plauts in standing water during June and July of 1884 and 1885 near Minneapolis.

The group of genera termed *Macrodactylea* or *Longiseta* includes such animals as have a more or less elongate and frequently cylindrical body, often strongly curved, and possess the following characters. The cuticle is considerably indurated; the terminal segment of the foot is long; there is usually a lack of symmetry exhibited by the claws or maxtax; and the cilia are sparse upon the trochal disc.

The following genera are at present included in the family:

Scaridium, *Monura*, *Furcularia*, *Distemma*, *Monocerca*, *Mastigocerca*, *Diurella*, *Heterognathus*, *Rattulus*.

GENUS DIURELLA, BORY DE ST. V.

The body is more or less perfectly cylindrical, and curved either ventrally or dorsally. The claws are rather long and frequently seem united, and are curved ventrally. The eye is cervical and single. There is a sensory tube upon the upper (dorsal) part of the disc. Three species are described, although doubt exists as to the specific value of one of these; they are *D. tigris*, Ehr., *D. Rattulus*, Eyferth, and *D. stylata*, Eyferth, to which a species is added below under the name *D. insignis*. The common species in America is

DIURELLA TIGRIS, (*Ehr.*) Bory.

The descriptions and figures of European authors vary remarkably in this instance, but from them all we are able to gather sufficient to make it reasonably sure that our species is really *D. tigris*. It is quite variable in size and form. The cylindrical body is strongly curved ventrally. The head is distinctly set off from the body by a suture as represented by Eyferth but not by Eckstein. The sides of the neck extend into a sharp spine on either side, which, however, may be easily overlooked. There is a sensory cylinder which forms a third prominence upon the front. The foot consists of but a single evident segment which is quite short. The appendages assume a variety of appearances. Usually they seem to form a flattened triangular plate curved in the same plane as the body. This appearance is figured by Eckstein, though he describes the appendages as consisting of two pairs, the outer half as long as the inner, both being united at the tips into one plate. Eyferth says, on the other hand, that the foot bears two unequal, bristle-like, curved claws, but his drawing shows two *equal* claws. Our experience confirms Eyferth's account. Like *Rattulus*, this species moves in circles or arcs of circles when lashing its tail, but has the power of moving in a straight line by the use of the cilia alone. The maxtax is nearly as drawn by Eckstein. The chief organs are two anchor-like indurated processes which are unlike in length and form. The walls of the maxtax are furnished with ring-muscles. The stomach is glandular and its cells contain large globules of fatty matter. The intestine is pear-shaped and furnished with numerous cilia. The contracting vessel is large but the lateral vessels are not easily seen and I can add no details. The single cervical eye is large and seated on a large elongate ganglion. The ovary is small and the egg, when present, occupies the left side of the body on its ventral aspect. The total length is about .20 mm. of which the body forms .16 mm. The longer claw measures, in large specimens, .048 mm. and the shorter only .036 mm. Sometimes I fancied that I saw two lateral spines as described by Eckstein. The width of the lorica is about .65 mm. This species was encountered in Ohio and Minnesota in all situations and seasons.

DIURELLA INSIGNIS, *sp. n.*

(*Plate IV. Fig.* 6.)

A larger species than the above is found in Minnesota. The length, exclusive of the claws, is from .17 to .20 mm. The claws are .06 mm. long, one being much longer than the other. There are spines in the cervical region similar to those described in in the above.

The body is much more slender, while the viscera do not differ essentially from *D. tigris.*

GENUS MONOCERCA, Ehr.

This genus includes elongated, nearly cylindrical or conical forms, having a single greatly elongated claw and more or fewer accessory spines on the last segment of the foot. The maxtax is elongate, with unequal indurated ridges. The stomach is oval and the intestine cylindrical.

The only specimens of this genus as yet seen resemble very closely *M. rattus* of Ehrenberg but are somewhat longer. The lorica is .30 mm. long while the claw is .22 mm. The foot consists of two segments, both of which are very short, while the last carries four or more unequal spines. The pulsating vessel is elongate oval but the details were not studied. This rotifer it quite rare.

GENUS DINOCHARIS, Ehr.

The lorica is cylindrical or prismatic, with a wide opening in front. The head is distinct and feebly ciliated. The eye is cervical. The foot is long, rigid, and three jointed. The claws are long and the foot bears, beside these, long spines anteriorly and behind. The whole shell is densely covered with granulations or spinules.

Dinocharis Pocillum, *Ehr.* (?)

(Plate II. Fig. 1.)

The most abundant form of this genus in America varies so greatly in both size and details of structure that one is tempted to identify it with the most frequent species of Europe in spite of variations from the descriptions of authors. The outline of the lorica is cup-shape and its symmetry is broken by two ridges near the posterior edge, passing transversely. It is 1 1-5 times as long as wide. The first segment of the foot is short and bears two long curved spines above. The middle joint is twice as long and nearly cylindrical. The third segment is about as long as the first and bears two curved claws four times as long as the segment and also a short spine about as long as the segment.

The whole body is about .24 mm long, including the claws, which measure .08 mm. The eye is large and is seated on an ovoid ganglion. The ovary is large and the nuclei are quite distinct. The egg is obliquely placed and nearly as long as the width of the lorica. Two curved elliptical glands lie in front of the stomach. The lateral vessels of the vascular system are large. Encountered only in Minnesota.

A somewhat larger form, also found in Minnesota, has more slender claws and seems to lack the spine on the last joint of the foot. The shape is otherwise the same.

The cast-off shell of still a different form, in which there is an indication of segmentation near the anterior of the lorica, was once seen.

GENUS SALPINA, EHR.

Somewhat resembling *Euchlanis*, but having spines upon the front and posterior margins of the laterally compressed lorica. There is a median area above, which is less perfectly indurated than the sides, giving rise to two ridges. The foot is short, three-jointed, and bears two lanceolate claws. The eye is single and the ciliation of the trochal disc rather strong. The maxtax is large and the digestive tract well differentiated. Water-vascular system with two or three beaker-cells on either side. The egg is carried about with the parent after extrusion.

SALPINA AFFINIS, *sp. n.*

(Plate II., Fig. 4.)

This species is so allied to *S. mucronata*, Ehr. that it is with some hesitation that a new name is proposed. While agreeing in most characters, it differs from that species in having the upper pair of anterior spines much longer than the lower and curved downward and in having the lower pair of posterior spines much longer than the single upper one and curved upward. *S. mucronata* is said to measure but .15 to .16 mm., while our form is .22 to .24 mm. long and .10 mm. wide. The anterior spines measure .045, length of claws, .06 mm. The whole shell is granulated and there is a band in front, set off by a distinct line. There is a sensory tube which bears a bundle of cilia at its end, and which usually projects from between the two dorsal spines of the lorica. The eye is lunate and seated on a very large, almost spherical ganglion. The maxtax is very large and opens into a slender œsophagus. The stomach is glandular and saccate. The very large egg is ventral. No careful study was made of the viscera. Minneapolis, May.

The species of the genus, aside from those mentioned, are *S. spinigera*, Ehr., *S. brevispina*, Ehr., *S. ventralis*, Ehr., *S. bicarinata*, Ehr, *S. redunca*, Ehr., *S. dentatus*, Duj., and *S. polyodonta*, Schm. There is reason to suppose that several of these are but varietal forms.

GENUS MONOSTYLA, EHR.

Shell depressed, oval; head opening large, notched before and behind. The foot has two short basal segments and a long terminal one ending in a small spine, hence appearing as though bearing one long spine. The eye is single and situated at the base of a large ganglion. The maxtax is large and quadrate. The viscera are simple.

MONOSTYLA (QUADRIDENTATA, *Ehr.* ?)

Two species of Monostyla have been thus far encountered, one of which may be identical with *M. quadridentata* of Ehrenberg. The body is bell-shaped or inverted pear-shaped, the oral margin being produced into two sickle-shaped spines turned outward, which are distinct from the acute margins of the shell itself. The body is composed of two segments or apparent segments, the second being small and conical. The terminal joint of the foot is slender and elongate, bearing a thorn-like spine. The ganglion is very large. The maxtax is also large and opens into a sack-like alimentary canal not evidently subdivided. The shell in this species is ornamented with granules. Length of lorica, .15 mm., width, .11 mm., terminal caudal joint, with spine, .08 mm. Found in June, in Minnesota.

A second species is smaller, measuring from .11 to .12 mm., foot .04 to .08 mm., width, .11 mm. The shell is smooth and the curved spines are absent.

The following species are known :—

Monostyla lunaris, Ehr., *M. cornuta*, Ehr., *M. closterocerca*, Schm., *M. oophthalma*, Schm., and *M. macrognatha*, Schm.

GENUS DISTYLA, ECKSTEIN.

Shell ovate conical, closed behind, except for the small opening admitting the foot. In front, the opening is wide and guarded on either side by projecting angles. The foot is one-jointed and bears two equal, divaricated spines. The shell may be smooth or ornamented with raised lines and serrations. The eye is single and seated upon a considerable ganglion. Two species are described by Eckstein from Europe (*D. gissensis* and *D. ludwigii*) and two additional ones occur in America.

DISTYLA MINNESOTENSIS, *sp. n.*

This is a large species, .25 mm. long, with a pear-shaped body of two segments, the first being .20 mm. long and of equal width. The second segment is .05 mm. long and has an oval slit behind for the insertion of the foot and permitting its free lateral motion. The claws are .13 long and slender, the terminal third being attenuated. The ganglion is small and bears a single red eye. The trochal disc is retracted by four powerful muscular bands. The stomach is globular and glandular. The short segment of the foot is moved by pairs of evident muscles. This species was but once seen in July.

DISTYLA OHIOENSIS, *sp. n.*

The lorica is .12 mm. long and its form is much as in the previous species. Width of lorica .084 mm., length of claws .028 mm. The sides of the lorica project in front to form a tooth on either side of the head. The lorica is sculptured into regular areas upon the first segment. There is a quadrate plate projecting over the base of the claws. The latter are attenuated toward the end. The details of structure are not known.

GENUS SQUAMELLA, EHR.

The three genera *Squamella*, *Metopidia*, and *Lepadella* agree closely together, being characterized by the presence of four, two, or no eyes respectively. The organization is much as in Euchlanis. The lorica consists of an oval, arching, scale-like shield above, and a flattened plate below. The foot consists of three short joints terminating in two acute claws The head terminates above in an oval scale-like appendage.

They only species belonging to this group as yet seen was hastily identified with *Squamella bractea* and, in absence of further information, we will simply give measurements in addition to the figure, in which, by the way, but one pair of eyes is represented, leaving us to infer that the animal is *Metopidia* rather than *Squamella*.

Length .08 mm.—.14 mm. Width (in the latter case) .12 mm. Found several times in Minnesota.

GENUS STEPHANOPS, EHR.

The lorica is depressed, and frequently extends into spines posteriorly Head covered with a shield, which, when viewed from before or behind, is in shape like a halo There are two eyes, occupying the extreme sides of the head. The foot is three jointed and ends in two lanceolate claws, between which springs an awl-shaped spine.

STEPHANOPS MUTICUS, *Ehr.*

(*Plate X, Fig. 9.*)

A specimen of this species was taken in July, 1885. The lorica is oblong oval, seeming two-jointed behind. There is a slight crest above. Both segments extend dorsally into prominences which only appear when the animal is viewed from the side. The head is covered by a thin semi-circular shield, which is slightly arched. The cilia of the disc are feeble, but the sensory tube is distinctly seen. The first joint of the foot is quadrate, the two following being of equal length but different diameter. The claws are ovate lanceolate and short. The accessory spine is awl-shaped and shorter than the claws. The length is about .10 mm Eckstein gives very good and accurate figures of this species, his description of the viscera is also valuable.

The following species of this genus are known: *S. lamelleris*, Ehr. with three spines behind. *S. cirratus*, Ehr. with two spines behind. *S. longispinatus*, Tat. *S. ovalis*, Schm. *S. tridentatus*, Fr.

GENUS BRACHIONUS, Ehr.

A large genus containing curiously armed and ornamented species. The body is depressed, oval or quadrate in outline, presenting a very large anterior opening always guarded by spines or teeth. Behind, the shell may be rounded or armed with spines like those in front. There is only a small opening upon the ventral aspect through which extends the foot. The ventral surface of the body is generally plane while the back is arched and may be set off into areas by elevated lines. The maxtax is prismatic and complicated. The egg is carried about attached to the body of the parent, as in *Anuræa*. The males are said not to be rare in this genus.

Brachionus bakeri, *Ehr.*

A single gathering taken in Granville, O., in September, contained a species belonging in the section of this genus characterized by the multiarticulate foot.

Our species is sub-quadrate in outline and more or less expanded back of the middle. The whole length, including spines, is from .30 to .40 mm. for adult females. The oral margin, above, is produced into six spines. The median pair are longest and curve decidedly outward and may be from .05 to .08 mm. long ; between them is an incision, through which ordinarily projects the sensory tube. The outer pair of spines are half as long and also curve outward. Midway between these pairs is a short spine or tooth. The ventral edge is notched in the middle, but not toothed. The width of the body is from .18 to .22 mm. The posterior portion of the shell extends into two pairs of spines, of which the outermost are very long (.10–.14 mm.) and project directly backward or slightly outward or are uniformly curved. The inner pair of spines immediately border the opening for the exit of the foot and are curved plates. The foot, which can be almost wholly withdrawn within the lorica, is composed of a closely ringed basal portion terminated by a short rigid joint, bearing two conical claws and blunt processes. The claws are perforated by the ducts of large cement glands. The flexibility and extensibility of the foot are truly wonderful. The whole shell is covered above with fine granules, but is not otherwise marked. The eye is large and is seated on the ventral side of a large ganglion. The maxtax is very wide and short. The manubrium is a curved plate and the uncus consists of several fused plates (see drawing). I have seen the animal attempt to masticate a large diatom and, after failing to crush it, reject it by reversing the usual movement of the jaws. The pharynx is ciliated and funnel-form. The œsophagus is not ciliated, but has ringed muscles which, when in motion, give the appearance of a valvular arrangement. The stomach and intestine are strongly curved upon each other, the former being glandular with fatty spheres in its walls, while the latter is furnished with a dense coating of cilia. The pulsating vessel is not large, but the lateral vessels with their beaker cells are quite conspicuous. This species, which agrees with ***Br. Bakeri*** closely, is common in Ohio, (September).

Another species, known only from a single gathering and imperfectly studied, differs from all known species in having a single pair of spines before and behind and a foot which at the base is multiarticulate, but ends in the two long segments, the last with two quite long claws. The shell is nearly smooth. This species may be called *Br. intermedius*, as it partakes of the characters of both sections.

BRACHIONUS MILITARIS, *Ehr.*

(*Plate X, Fig. 10.*)

It is interesting to compare with the above a related species which is quite common in the west and which belongs to that section of the genus characterized by the absence of the ringed basal arrangement of the foot. This form, which may not be properly Brachionus, resembles decidedly the above in the form of the body. The anterior margin extends into ten teeth, of which the superior median are longest and curve ventrally. All the other anterior teeth are doubly curved, the points extending outward. The posterior part of the body bears two pairs of spines, the relative position (and size) of which is not constant. The outer pair are always longer and project outward and backward. The foot consists of three slender joints, the last of which bears two lanceolate appendages somewhat longer than the segment preceeding. The whole shell is covered with minute points. The trochal disc is broken up into five lobes and the cilia are of two sizes. The measurements of one specimen are given as illustrating the proportions. Length .20 mm. exclusive of foot, width .14 mm., terminal stylets .024, lateral, posterior spines .028 mm., anterior spines about .04 mm.. From the side, the ventral surface (in outline) is seen to be plane while the dorsal is composed of two inclined planes (or is "humped.") The foot is moved by two pairs of muscles. The contracting vessel is unusually large. The maxtax and the position of the viscera seem to be as in other species of Brachionus. The animal seems most to resemble *B. militaris*, Ehr. of the European species.

PLŒSOMA LENTICULARE, *gen. et sp. n.*

(See figures facing Index.)

The animal for which the above generie name is proposed, was several times seen in a gathering taken at the reservoir near Hebron, Ohio, in November. The general form is very similar to that of many minute bivalved crustacea (*Chydorus*), with which it was associated. The lorica is composed of two ovate valves, which are partially united below, so that the foot springs from the middle of the ventral margin. The animal is laterally compressed. On the dorsal aspect of the lorica are several distinct ridges arranged about as follows: A pair of short transverse markings occupy a point posterior to the middle of the dorsal aspect; anterior to these, and beginning at either end, spring diverging lines which lead to notches of the anterior margin; behind, two ridges lie on either side the median line and extend to the acute posterior end of the shell. Several lines border the above described markings on either side and are approximately parallel to the axis of the body. Seen from the side, the lorica is elliptical and is truncate in front and acute behind. The dorsal line is a uniform curve, while the ventral is prominent near the middle at a point some distance in front of the point of union of the valves. Seen from above, the front half is quadrate, while the posterior half is triangular. The lorica is lenticular, considered as a whole, and is marked by minute hexagonal or irregular depressions.

The head is armed with two long sensory organs and has two sorts of cilia. The outer series is quite feeble, but the ventral prominence bears several elongated setæ. The maxtax is oval and seems to be but slightly armed. It is furnished, however, with distinct annular bands of muscles. The eye is cervical, and is seated on the under side of a considerable ganglion. The foot is multiarticulate at the base, as in *Brachionus*. Two distinct joints follow this portion, the last being longer and bearing two oval, appressed spines. Of the internal organs little was seen. The stomach is glandular and the egg of but moderate size. The vascular system was not seen.

Length, .24 mm., height, .15 mm., width, ,10 mm. Frontal processes, .03 mm., spines of foot, .025 mm., last joint, .02 mm.

GENUS ANURÆA, EHR.

Closely related to *Noteus* and *Brachionus* is a genus of curious rotifers in which the foot is entirely absent ,so far, at least, as can be seen. As in Brachionus, the anterior opening is protected by spines or teeth, while there may or may not be simtlar teeth behind. The lorica is usually distinctly separable into a dorsal and ventral shield, and the dorsal scutum is marked off into geometrical figures by raised lines. There is a single cervical eye Tbe egg very generally remains attached to the body and may be mistaken for a part of it.

ANURÆA SP.

A species differing from all European forms is very common in the West. The form is hexagonal in outline, the length being 1.4 times the width (exclusive of spines). The anterior margin of the hexagon is wider than the posterior. The dorsal scutum is produced into six long spiny teeth, of which the middle pair are much the longest and are strongly curved outwards and downwards. The remaining pairs are sub-equal and project outwards like the horns of an altar. The ventral part of the anterior margin is excavated in the middle and bears a series of small sharp teeth. The whole shell is ornamented with circular prominences, and, in addition to this, above there are strongly raised lines blocking off the shell into thirteen regular areas and leaving two other areas about the front. The character of these ridges is best seen from a side view. The eye is cervical and the trochal cilia are strong for the genus. There is also a sensory tube.

The following measurements, owing to an accident, may not be accurate, but will give the proportions: Length, .1 mm., width, .054 mm., longest spine, .024 mm.

GENUS PTERODINA, EHR.

The lorica is flattened, round, or ovate in outline and flexible. Head funnel-shaped, entirely withdrawn into the body when at rest, furnished with two lines of cilia. Stomach sac-like with large cilia. The foot is ventral and consists of a ringed basal portion and a short terminal joint which bears no claws. The intestine is said to be continued through the tail having the anal opening at its end.

The Pterodina is a good subject for use in obtaining a knowledge of the rotifers as the viscera are quite distinct, the cross striation of the muscles and the ciliated or beaker-cells of the lateral vessels being particularly distinct.

PTERODINA PATINA, *Ehr.*

(*Plate* 1, *Fig. III.*)

The form is circular with a slight emargination in front for the withdrawal of the head. The head is funnel-shaped and bears a double disc having good sized cilia. When extended, the eyes are seen to occupy a position about one-third the width of the disc from its sides. The pharynx is closely ciliated and leads into a comparatively large maxtax in which a partial fusion of parts has taken place. The stomach follows upon a very narrow oesophagus and is a curved sac composed of large cells, each of which is filled with granular contents and has fatty spheres within it. On either side the stomach is a strong muscle passing from the sides of the head to the posterior third of the body where it is fastened. When the head is withdrawn the muscles are curved, but upon the protusion of the head become straight. On either side the stomach is a large glandular mass composed of numerous lobes made up of fused cells with large translucent flecks which may be globules of the secretion. These glands open back of the maxtax. While the stomach is curved to one side, the intestine lies behind the tail and is curved upon itself, opening, as claimed by Eckstein, into a canal excavated in the tail. It is indeed certain that the tail contains a canal and is ciliated at the distal extremity but we have never been able to verify the statement referred to. The tail seems to be more slender in our specimens than figured by European writers, though it is exceedingly contractile. The contractile vessel seems to be absent but two very distinct lateral canals are to be seen. The breaker vessels are long and the cilia active. The ovary occupies one side of the body, while the egg nearly fills the other when mature. Large nuclei are discernible imbeded in a granular mass of yolk. The margin of the shell seems to be granulated and extends beyond the body-cavity. The tail often is directed at right angles to the body and is then overlooked. The lorica is about .20 mm. in longest diameter. The tail measures over .07 mm. The trochal disc, when expanded, is .05 mm. wide. A small specimen, but fully adult was but .17 mm. long. Mr. Stokes mentions a species of this genus but does not identify it. There are two other species, viz. *P. elliptica* and *P. clypeata*, Ehr., which latter occurs as a parasite on species of *Assellus.* I have a confused recollection of having seen such a rotifer parasitic upon *Gammarus. Pterodina complanata* of Gosse is almost certainly identical with *Pt. patina.*

FAMILY ASPLANCHNÆA.

This family includes abberant rotifers, which lack the posterior opening of the digestive organs and are considerably reduced in other respects. The foot is sometimes almost entirely absent, its position being marked in these cases by the glands simply. The body is saclike and often consists of a single segment in which the various internal organs are very readily seen. The head is broad and sparsely ciliated. The maxtax is enlarged and to it is appended an extensible crop, while the incus is not highly indurated and the mallei are modified to form a prehensile pair of nippers or pliers. The stomach may be very extensible and a part is very highly glandular. The water-vascular system is highly developed and there is generally an accessory canal bearing the minute beaker cells, while the lateral vessels themselves are tortuous and elaborate. Most of the species are carnivorous, while others live upon algæ and like plants.

GENUS ASPLANCHNÆA, GOSSE.

The genus is characterized by the sac-like body and the large size and well differentiated organism as compared with *Ascomorpha.* The details mentioned under the family apply.

ASPLANCHNA MAGNIFICUS *sp. n.*

(*Plate II, Fig.* 2.)

This, the largest species of the genus, is most like *A. Myrmeleo*, but is considerably larger and appears to differ from it in several other particulars. The general form is a prolate spheroid truncated anteriorly and slightly flattened ventrally. The oral end is furnished with six discrete clumps of cilia and two sensory processes. The crop is large and distensible, the forceps are smooth and toothless. The œsophagus is long and muscular. The stomach is composed of very large cells and is held in place by bands of connective tissue. There are accessory glands between the stomach and crop. The ovary is pear-shaped (not horse-shoe-shaped, as in *A. Myrmeleo*), and can be seen to be made up of an elongated ribband of cells folded upon itself. The pulsating vessel is exceeding large and powerful, while the lateral vessels are convoluted canals; accessory to the latter, there are nearly straight tubes bearing about twenty beaker-cells. The foot is two-jointed and contains small glands. The muscular spstem is highly developed and consists of strong bands passing backward from the head and frequently branching before they are inserted upon the very pliable external wall. Two pedate cells lie upon the viscera and may represent the visceral nervous system. The nervous system was otherwise found to consist of ganglia upon the oral aspect, one of which bears a single red eye, and which send nerve-fibers to all parts of the body. The animal feeds upon species of minute crustacea, especially of the genus Chydorus. The greatest length is .9 mm., width, .66 mm., foot, .15 mm. This species was figured in the writer's Final Report on the Crustacea of Minnesota, where also may be found the figure of

ASPLANCHNA *sp?*

This species, which seems to resemble *A. Brightwelii* of Gosse, is purse-shaped, being constricted about the head. The jaws are bidentate at the end and ribbed. The foot is entirely absent, but its position is indicated by the orifice of small glands. The stomach of the only individual of this species seen contained a number of the lorica of what may be *Anuræa longispina*, Kellicott.

EXPLANATION OF PLATES.

Plate II.

Fig. 1. *Dinacharis pocillum*, Ehr.?
Fig. 2. *Asplanchna magnificus*, sp. *n.*
Fig. 3. *Euchlanis ampuliformis*, sp. n.
Fig. 4. *Salpina affinis*, sp. n.

Plate III.

Fig. 1. *Pterodina patina*, Ehr.

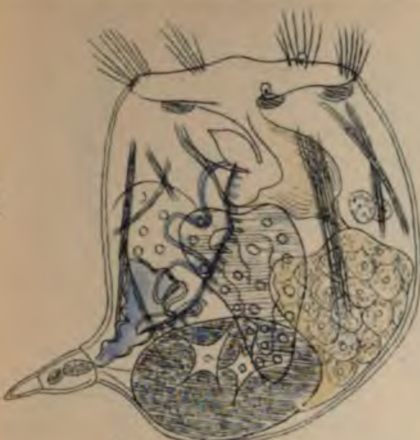
Fig. 2. *Euchlanis hipposideros*, Gosse.
Fig. 2.^{1} do portion of lateral vessel with beaker cell.
Fig. 3. Undetermined.
Fig. 4. *Amphileptus gigas*, C. & L.

Plate IV.

Fig. 1. Undetermined
Fig. 2. *Squamella bractea*, Ehr.
Fig. 3. *Monostyla quadridentata*, Ehr, (?). The foot is somewhat too lo the drawing.
Fig. 4. *Polyarthra platyptera*, Ehr.
Fig. 5. Undetermined.
Fig. 6. *Diurella insignis*, sp n.

Plate X.

Fig. 5. *Spirostomum teres.*
Fig. 6. *Ophridium paradoxum*
Fig. 7. *Anuræa* sp.
Fig. 8. *Distyla Minnesotensis*, sp. n.
Fig 9. *Stephanops muticus*, Ehr.
Fig. 10 *Brachionus militaris*, Ehr.



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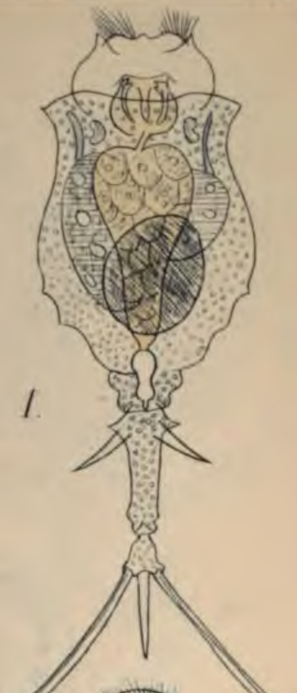

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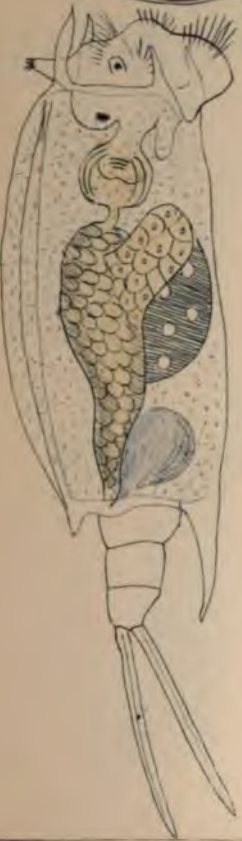

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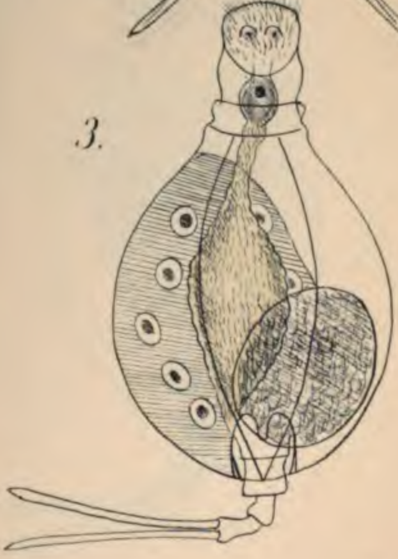

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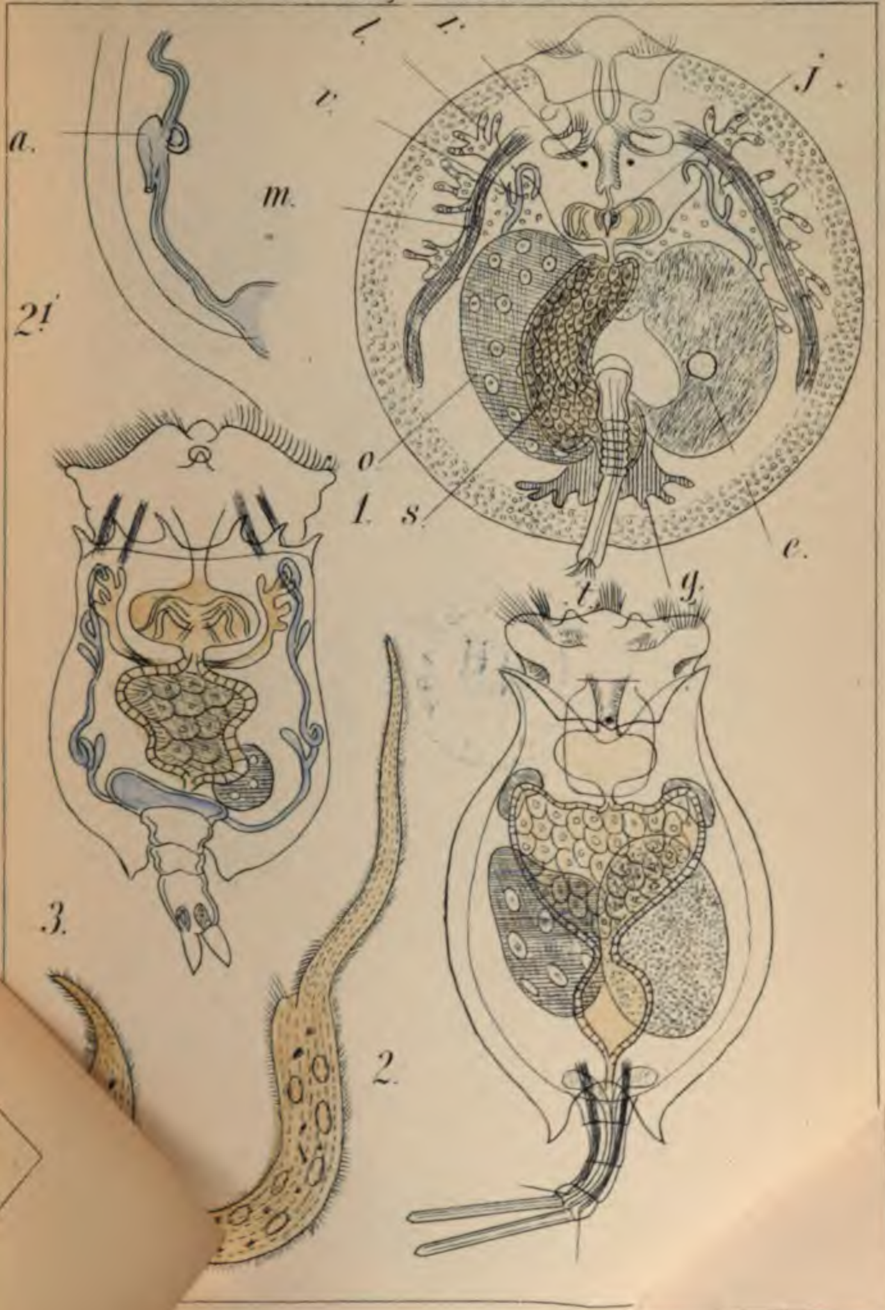
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Fig. 2. *Euchlanis hipposideros*, Gosse.
Fig. 2.[1] do portion of lateral vessel with beaker cell.
Fig. 3. Undetermined.
Fig. 4. *Amphileptus gigas*, C. & L.

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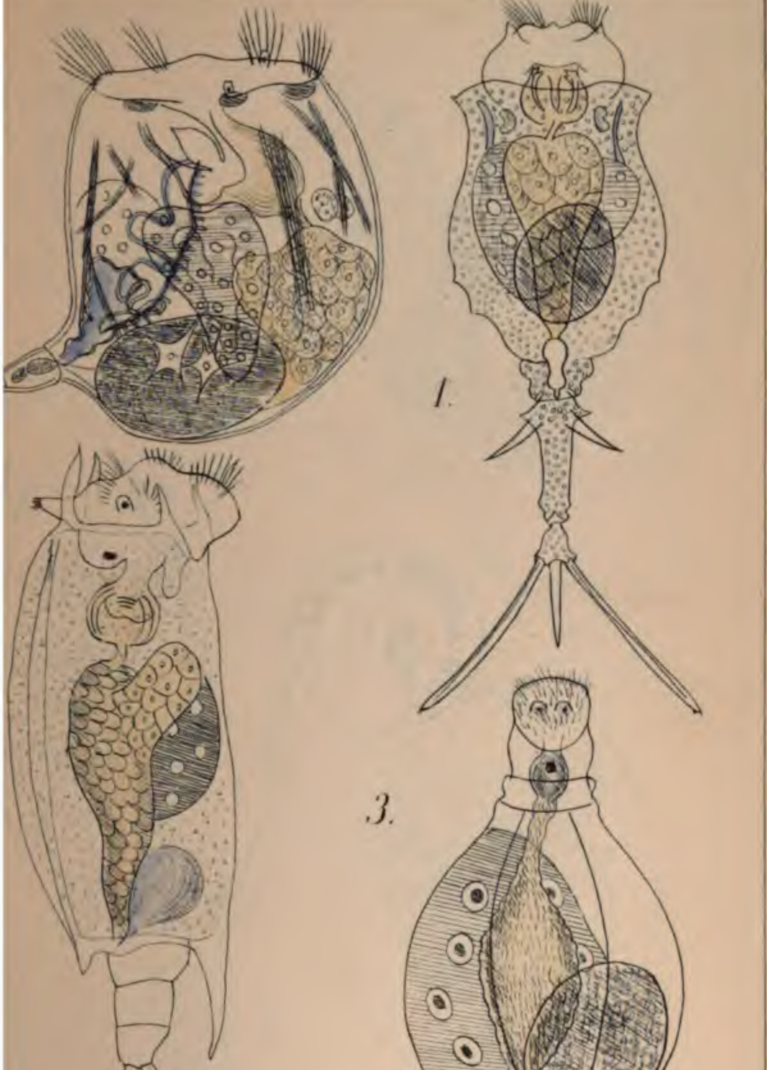
Fig. 9. *Stephanops muticus*, Ehr.
Fig. 10 *Brachionus miliatris*, Ehr.

of Denison University Laboratories. Vol. I. Plate II.



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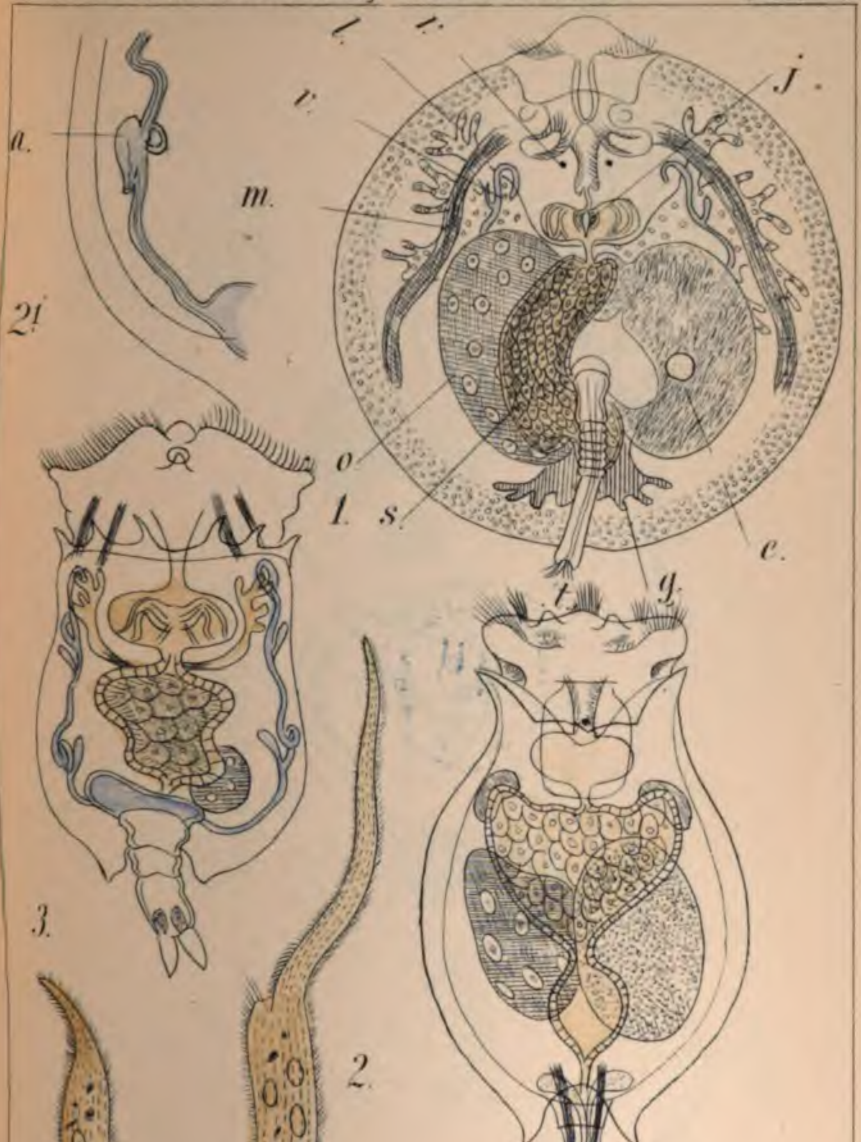

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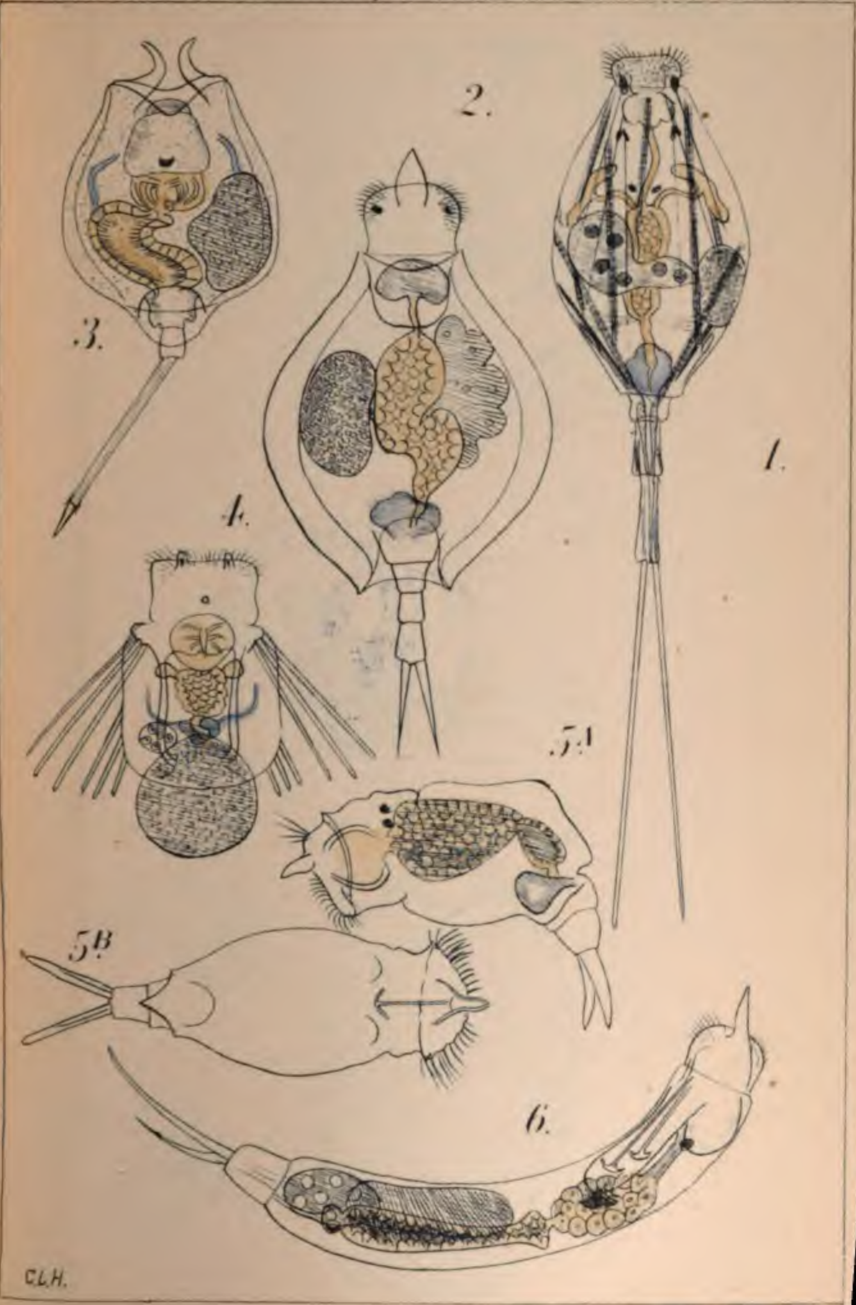

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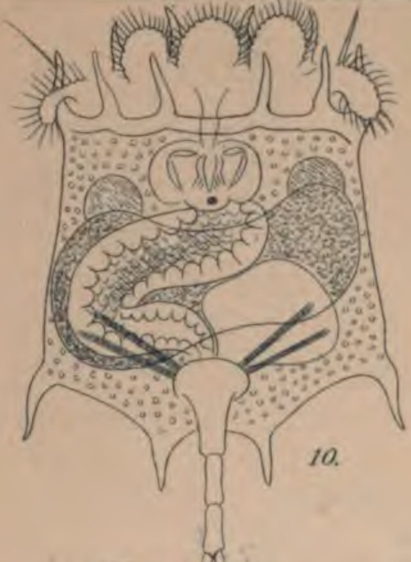

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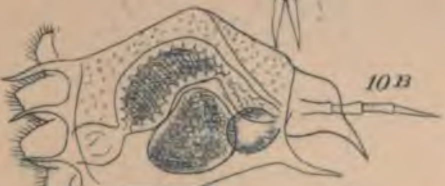

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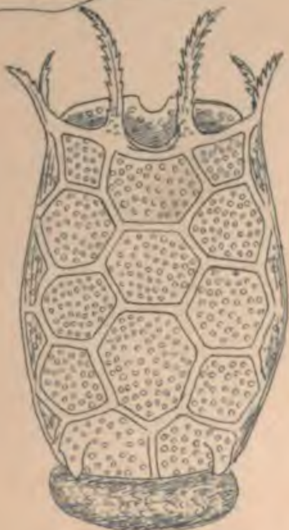

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VI.

THE CLINTON GROUP OF OHIO.

BY A. F. FOERSTE.

Prospectus.

The title, as given above, does not correctly indicate the scope of the papers here presented, but, will very well serve to designate the field which I have laid out before me, and which I expect to cover by means of a series of articles, of which the present paper is the first. Descriptions of all the important exposures in the state, sections of the strata, analyses of rock, and paleontological features will be furnished wherever practical. A collection of fossils, which already bids fair to rival those at Waldron, Indiana, is expected to furnish the basis of a description of the fossils of the group as presented in this State. It is also intended to identify in an independent manner the true relations of the geological strata usually included by the name Clinton Group, in our State and Indiana. Although it may be well to state at the outset that present indications seem to favor a closer relationship to Niagara strata, and especially those of the west, than is generally conceded ; nevertheless this conclusion has not been hastily drawn, and is not irrevocably held. I shall only attempt to present the facts and state their probable bearing, and then allow the reader to draw his own conclusions. In order to determine more definitely the stratigraphical relations of the group with corresponding formations of the west, especially those of Indiana, a series of sections taken at different stations, from both Ohio and Indiana, will be undertaken at an early date. Although the project in some respects may seem rather extensive, the large amount of material already collected gives promise of its ultimate accomplishment.

GEOLOGY.

In southwestern Ohio, immediately above the Cincinnati Group, lie a series of strata, formerly known, both scientifically and popularly, as the Cliff Limestone. They are so designated, for instance, in the second annual report of the Ohio Geological Survey, undertaken in 1838, by W. W. Mather. Many of the cliffs and cascades in this part of the State owe their origin to the peculiar characteristics of this formation. Later, however, a division into two groups was made, and after a more extended study by Prof. Edward Orton the upper section was identified with the Niagara Group, but the lower was called the Clinton. In the reports for 1869 and 1870, these distinctions were carefully made. At various times, however, authors have seen fit to express doubt of the correctness of the name employed for these strata, and Prof. James Hall, especially, has had occasion to do so in the 12th annual report of the Indiana Survey. For our purpose it will be well enough to retain the name, Clinton Group, at least for the present, but it is expected that after a presentation of all the facts, others, perhaps, will be ready to adopt some other term.

The Clinton is not a group of any great depth. For its western exposures in Ohio, ten to fifteen feet would be a fair estimate. In its eastern exposures in Highland and Adams counties "its *average thickness* is somewhat increased, but probably never exceeds 40 feet, and this thickness is sometimes attained in the northern district as a *maximum*, as for instance, at Yellow Springs, in Greene county." (Italics my own). A section of the geological series of Highland County gives a thickness of 50 feet to the Clinton Limestone. (Geo. Surv. Ohio, 1870, page 298 and section at page 310.)

The Clinton Limestone rarely affords any extended surface exposures, but is found like a narrow line separating the Cincinnati and Niagara Groups of the State, and usually is seen in close connection with both. A section of rock belonging to the Clinton age, therefore, generally also includes both the upper and lower strata.

The rocks of the Cincinnati Group, in Ohio, are quite level, showing no marked local variations in their dip. At their junction with the Clinton Group, however, they frequently become unfossiliferous, and the rock is replaced by less solid shales and bluish clays. The surface of the group also becomes very undulating in character, frequently attaining a dip of four feet in forty. As a consequence the superposed rocks of the Clinton Group are also very undulating.

They maintain, however, an average thickness, indicating that, whatever were the causes which had disturbed the bed of the Lower Silurian sea, these had disappeared by the time the strata of the Clinton Group were deposited.

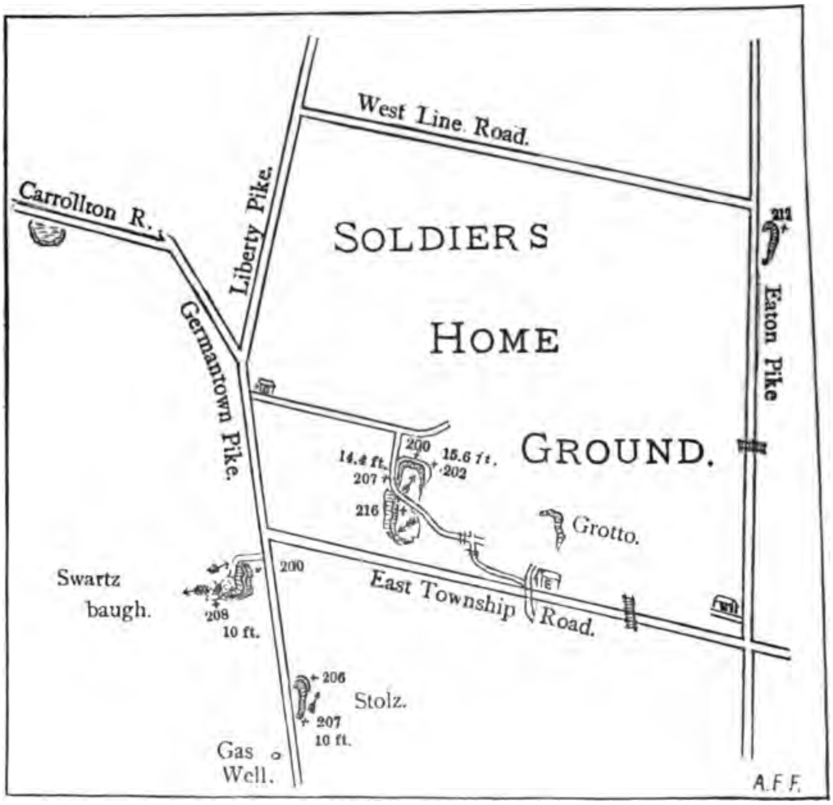
In other words, at the close of the Lower Silurian age, the ocean became shallow; large valleys and gullies were washed out from the beds of the Cincinnati Group. The silt was deposited as a blue clay, which terminates the strata referred to this age. On this uneven and very undulating bed, the rocks of the Clinton Group were deposited. At this time a portion of the Lower Silurian rocks must have been exposed, as the researches of the last geological survey revealed evident shore markings in several places, containing the pebble-washed fragments of the Lower Silurian strata.

In fact, the very fragmentary condition of most of the fossils found in this group indicates the action of shore waves upon the accumulated deposits of this sea. The slight variation in the thickness of the group may readily be explained by the conditions brought about by its uneven bed. The washings of an otherwise shallow sea would naturally be very unequally deposited near the shore line. At a distance from the land the fine silt would be almost equally deposited, but near the shore the washings would accumulate most in the depressions of the ocean bed. And, although the inequality of deposition would of course not be very great over any large extent of territory, nevertheless it is sufficient to account for the variation observed. At Soldiers' Home, where there is a dip of seven feet in one hundred, the rock increases one foot in thickness. This is the most marked instance which has fallen under my observation.

The Clinton Group consists of a crystalline, crinoidal limestone of variable color, sustaining a high polish, extremely fossiliferous in places, differing in this particular from the Niagara strata immediately overlying it.

Between it and the Niagara Group is a fine clayey or marly bed, about nine inches thick, which in some places becomes quite hard, and in others is replaced by a soft blue clay. In connection with the Dayton limestone it usually attains the hardness of stone and is characterized by a number of minute species, which, considering the small attention hitherto paid to this course of stone, is unusually great. For the present it will be called the Beavertown marl, on account of its prominent development near that village, and will be considered as a part of the Clinton Group.

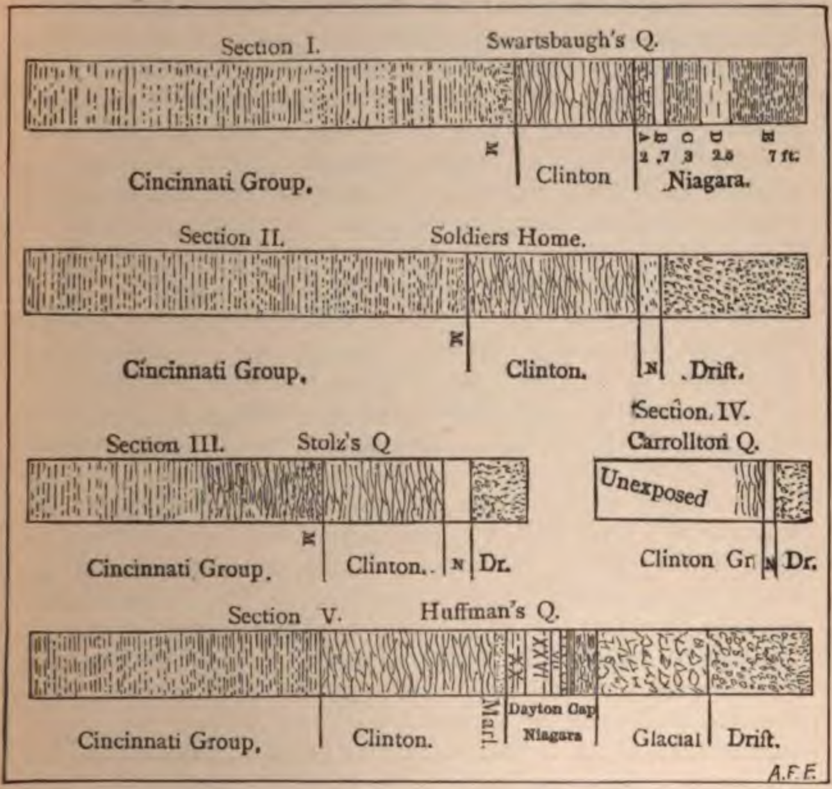
The first, and by far the most important series of exposures to be mentioned, are those included in the Soldiers' Home district.



SOLDIERS' HOME QUARRIES.

The Soldiers' Home grounds, embracing about a square mile of land, are situated two and a half miles west of Dayton, on a series of hills overlooking the city. At their foot, exposures of the Lower Silurian strata are frequent, but at their top, rocks of the Upper Silurian age take their rise, and have a steady dip towards the west, bringing up, one after the other, the formations of a higher age.

About half a mile from the Home, at the side of the Germantown Pike, a well, driven for water, gave rise to a flow of gas, lasting some months. Owing to neglect or other causes, the supply has now ceased, evertheless, the existence of inflammable gas in the Lower Silurian rocks is of some interest.



Stolz's Quarry, (Section III.)

A short distance westward, the pike runs upon a bed of rock belonging to the Clinton Group. North of the road a quarry has been opened, which displays both the Niagara and Cincinnati Groups, nevertheless a satisfactory section of the Clinton Group has as yet not been attainable.

All measurements of the elevation of rocks in the various sections are reckoned from the sidewalk at the Court House in Dayton. These measurements are due to the kindness of Mr. A. Kiehl, who aided me materially in this part of the work. The top of the Cincinnati Group is at 193.51 at the first station. In a section made near by the Cincinnati layer was not exposed but the lowest point in the Clinton was at 196.74; the top of the Clinton, 206.31; the top of the Niagara exposed, 208.68. The thickness of the Niagara was therefore 2 ft. 4.5 in.; and that of the Clinton, considering that the dip from the first named station, east of the section, was slight, but westward, a thickness of twelve feet would be more than conjectural. The rock is crystalline, consists of uneven "lenticular" layers, unequally fossiliferous, the fossils being found in "pockets" or special accumulations, irregularly disposed throughout the group. Numerous fine heads of *Dalmanites Werthneri* are quite abundant here, and for many things it ranks with the Soldiers' Home quarry itself in productiveness.

The Clinton ends in a top of blue clay containing large crinoid beads, free specimens of *Chaetetes*, *Rhinopora*, &c. It is about five or six inches thick. Only the blue clay referred to the Cincinnati Group is exposed. The Niagara Group consists of a yellow limestone, unfossiliferous as far as known, lying in uneven broken courses from two to five inches thick. It has no commercial value, but the Clinton stone is much used for academizing roads and streets, and is profitable on a small scale, as a gain of $492 with an expenditure of $426 in one instance will show. During this year, 1885, up to August an expenditure of $356 realized a gain of $547, which is quite profitable considering the small amount of time put upon the quarry. The inferior quality of the Niagara limestone at this quarry is to be especially mentioned as it is the exact equivalent of the Dayton limestone and the succeeding quarries farther west gradually assume the characteristics of the Dayton stone, thus forming a complete and instructive series for comparison.

Swartzbaugh's Quarry. (*Section I.*)

On the same pike within a few hundred feet from the south-east corner of the Home grounds is a second quarry. It is placed behind a farm-house, dipping northward into the hill near the barn. The top of the Cincinnati Group is here represented by a bed of blue clay. In the sections made, however, this bed was not reached. The bottom of the Clinton Group as far as worked was at 198.21 ft.; the top, at 208.04 ft.; but a conjectural thickness of twelve feet would not be far from correct. The stone presents the usual characteristics, but seems to be less fossiliferous than some of the neighboring quarries. It is peculiar in showing fissures, extending east and west, distant from each other about 9 feet, found at no other station in the Clinton Group. In the southern part of the quarry there is a sudden dip to the south and the stone is broken, as though the blue clay layer beneath had given way and permitted the stone to sink. The fissures in the rock are perhaps also explained in this manner.

The Niagara exposure is a little more than 15 feet in height. The base of the series is composed of broken, irregular, yellow layers of stone from two to five inches thick, making a total of 1.9 feet. Above is a 9 inch course of blue flagging stone, which was at one time quarried and sold in slabs for pavements. It resembles a fair quality of Dayton limestone of which it is the stratigraphical equivalent. Formerly when the Clinton stone was not exposed and the Cincinnati Group was in plain sight along the hill below, and the great dip of the rock had not yet been determined, the identity of this stone remained for a long time a puzzle. Above the blue flagging is a series of shales 3 ft. thick, varying in character, sometimes represented by broken courses of yellow limestone 2.5 ft. thick, composed of a nine inch layer above and below, with the intermediate layers more or less shaly in character. Sometimes the remainder also becomes somewhat shaly. Last in the series is a 7 ft. layer of yellow Niagara stone, formed of very broken, thin courses, from half an inch to two inches in thickness, frequently becoming shaly. The top of the blue flag layer in the southern part of the quarry is at 210.70; seventy-five feet north, at 204.10; fifty feet west, at 203.89. This would give a dip of 4 ft. 5 in. in fifty feet towards the north, and only 2.5 in. in the same distance, towards the west; the last dip is reliable, owing to the very even stratification of the blue flagging. At the same point the bottom of the heavy Niagara stone is reached at 206.92; the top at 209.49. Farther west the top is again reached at 207.87, and the summit of the thin shaly courses at 214.85. All the Niagara stone here exposed is unfossiliferous as far as known. In some parts of the quarry the Niagara stone is all tumbled together, destroying its original stratification. I presume that the action of ice during the glacial epoch could readily account for this, since all the quarries round about, where the stone is hard enough, show evidence of this glacial action in the form of grooves, scratches and the planed surfaces of the stone.

Carrollton Pike Quarry. (*Section IV.*)

Along the Carrollton pike about half a mile from the Home Grounds, on the east side of the road, a quarry was opened, which developed a layer of Niagara flagging stone 5 or 6 inches thick. It was smoothed above by glacial action, was found within two feet of the surface, and hence was readily worked, and sold to advantage as a fair quality of Dayton limestone. In several places in Dayton it was used without extra preparation for side walk purposes. Beneath is a layer of thinner stone and then limestone of the Clinton Group, of little or no commercial value, and therefore, not quarried. Here specimens of *Orthis fausta* were found. This species has also been found at Swartzbaugh's quarry, in the same position, namely at the very summit of the Clinton Group.

Eaton Pike Quarry.

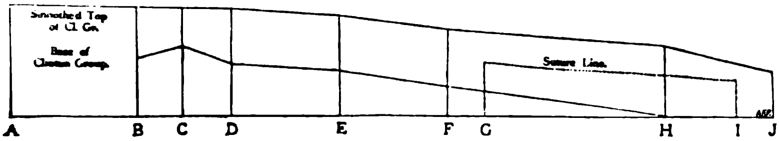
North-west of the Soldiers' Home grounds, on the north side of the Eaton pike the Clinton rock is quarried. Neither the top nor the bottom of the series is exposed but the two levels taken register 211.92 ft. and 205.50, which give a thickness of 6 ft. 5 in., but the real height of the strata is no doubt much greater. Numerous bryozoans are found here.

The Grotto.

East of the Soldiers' Home along the railroad, a cut through rock of the Cincinnati Group displays the characteristic fossils of this group. South of the terminus of the railroad in the grounds are the socalled grottoes. These were formerly the site of an old quarry, and belong to rocks of the Clinton Group. Owing to the underlying bed of blue clay the Clinton Group is usually a great water bearer. At Soldiers' Home one of the grotto springs is fed in this way, and two springs of the same nature in the quarry south of the grotto give forth a steady flow of water all year. The grotto is now used for floral effects only.

Soldiers' Home Quarries. (*Section II.*)

The Soldiers' Home quarry is the finest exposure of the Clinton Group in the State. Being constantly in operation, it has proved the most productive place for fossil remains. Both the Niagara and Cincinnati groups are shown in the same section, and the thickness of the Clinton Group as here obtained is strictly accurate.



	Top of Clinton Group.				Base of Clinton Group.					Seam in Clinton.			
Stations.	*Distances.*	*Height above Court House Corner.*	*Dip in feet*	*Dip for 100 feet.*	*Distances*	*Height above Court House Corner.*	*Dip in feet.*	*Dip for 100 feet.*	Stations.	*Distances*	*Height above Court House Corner.*	*Dip in feet.*	*Dip for 100 feet.*
A	150	208 95	1 00	.67	----	----	----	----	G	175	198 08	3.29	1.88
B	----	----	----		30	198.94	*2.08	*6.93	I	----	194.79	--	----
C	----	----	----		35	201.02	3.44	9.83					
D	75	207.95	1.38	84	75	197.58	1.17	1.56					
E	75	206.57	2.46	3 28	75	196.41	2.70	3.60					
F	150	204.11	3 19	2 16	150	193.71	5.54	3.69					
H	75	200.92	4.54	6.05	--	188.17	----	----					
J	----	196.38	----	----	----	----	----	----					

*Dip towards the west.

A section of the eastern half of the quarry, beginning at A near Massachusetts Avenue, and extending to the eastern limit, is represented by the table and section just given. The distances are reckoned to the next succeeding station on the line; the height is calculated from the level of the side walk at the Dayton Court House; the first list of dips consists merely of differences of elevation between consecutive stations; in the second these are reduced to the standard of 100 feet. The dip unless marked by an * is toward the east.

The difference in direction between the base and the top of the Clinton Group is quite evident, and is owing to the effects of glacial action which has planed off the stone without regard to its dip, or elevation, as shown for instance at station C. This is still more evident if the dip near the western end of the section be considered, where the base of the Clinton is 4 ft. below the same 40 feet north. The entire eastern half of the quarry shows glacial scratching, planing, and grooving.

It is frequently supposed that the Clinton contains no regular seams, separating the strata. Whereas this is true in a general sense, as compared for instance with Cincinnati or Niagara formations, nevertheless quite regular seams are occasionally found also in the Clinton group, especially in the section now under consideration. A long seam, followed with comparative ease for 175 ft. showed a dip of 3.29 ft. in this distance. A comparison of this line with the base of the group shows that the strata thicken in the depressions of the underlying bed. This is also shown in the western half of the quarry, where the group is 14.4 ft. thick at the spring, and 15.6 ft. at a point 150 ft. north-west of the same, showing an increase of 1 ft. 2.5 in. The elevations at the spring are: top of Cincinnati group 192.63; of Clinton group, 207.01. Along the western end of the quarry the elevations of the Clinton: are 202.73 at the S. W. corner, 200.07 at the middle, 202.15 at the N. W. corner, 202.36 at a point east of the latter. Here the top of the Niagara reached 204.26 showing a thickness of 1.9 ft.; it is a yellow, somewhat shaly stone, becoming frequently quite hard. Taking the Niagara stone as shown at the Soldiers' Home, Carrollton pike, and other quarries farther west, a good idea of the variability of the base of this group can be formed. In the western part of the quarry the base of the Clinton Group consists of a greyish or almost white stone, composed of finely comminuted organic remains, of which the structure has become more or less obscure. Here many bryozoans have been found in a fine condition. *Clathrapora Clintonensis* and *Retepora angulata* in fronds 2 feet and 1 foot in diameter respectively have been seen here. Other fossils, however, are rather scanty in this stone. Most of the group, however, is composed of a bluish solid limestone, becoming pinkish or red by oxidation, and abounding in fossil forms. The summit of the group in the north-western part of the quarry is especially prolific in various species of *Orthis*. The summit of the Cincinnati Group is composed of blue, clayey shales, several feet thick, and very undulating. The notable fact is that these undulations are mostly local, the strata taken as a whole, maintaining a comparatively even inclination, as will be seen by a reference to the map.

In the rocks of the Clinton Group, at Soldiers' Home, so many species are found, and so much work has been done, that it would be difficult to mention the prominent features. Bryozoans, found here in numbers, are said to be still more common at the Eaton pike quarry, *Platyostoma Niagarense* is not unfrequent. Glabellæ and pygidia of two species of *Illænus*, are abundant, as are also various shells, corals, &c. The fossils are not equally distributed. Thin courses of rock are not apt to be very productive. In the thicker interspersed layers, however, which show external signs of fossils, considerable numbers are frequently developed by breaking the stone. Throughout the Clinton Group the fracture is irregular, and it is very difficult to obtain entire specimens. It is rarer still to obtain specimens completely loosened from the rock, as one or the other face is apt to be inseparably connected with it.

DAYTON LIMESTONE QUARRIES.

South of Dayton a continuous series of quarries extends from Beavertown to a point about a mile and a half northeast of the Insane Asylum. Some of these have been abandoned, but in those now in operation the Dayton and overlying strata of the Niagara are shown in section, and small exposures of the Clinton are not infrequent. As a means of comparison with the district just described, a section of one of these quarries is given.

Huffman's Quarry, (Section V.)

About three quarters of a mile towards the southeast of the Asylum for the Insane, is a quarry, belonging to Mr. W. P. Huffman, of Dayton. A single section of the Clinton Group is said to have been obtained here, while constructing a drain. The strata were 13 feet thick; the color is light pink, and its fossils are rather few. The Niagara Group consists of the Dayton limestone, and a few layers of "blue cap." The Dayton limestone consists of a 20 in. course of stone, surmounted by a 26 in. and a 7 in. course. The 20 in. course separates into a 12 in. layer, succeeded by two 4 in. layers. The 26 in. course, even more readily, is divided into a 20 in. and a 6 in. layer. The 20 in. layer is naturally the most profitable, and is quarried in large slabs. The blue cap begins with a 10 in. course of poor quality, followed by an 8 in. course, still more inferior and often broken. Above this, 18 in. or more of thin slabs, usually in small pieces, may be found. The color of this blue cap is denoted by its name; its commercial value is destroyed by its poor weathering qualities and the irregular and broken condition of the stone. The quarry, therefore, presents four and a half feet of good Dayton limestone. The Niagara cap is here unfossiliferous as far as known. The Dayton limestone contains corals and orthocerites. Between the Clinton strata and the Dayton limestone is a bed of blue marl, 9 in. thick, which is referred to the Clinton Group. It contains large crinoid beads, *Orthis biforata, var. lynx*, and various minute forms not known elsewhere in the series. The Clinton Group proper has furnished a pygydium referred, doubtfully perhaps, to *Illænus Madisonianus.* The marl is in this paper called Beavertown marl.

CENTREVILLE QUARRIES.

Centreville, eight miles south of Dayton, is situated on an outlier of stone, composed of rocks belonging to the Clinton and Niagara groups. In some places that division of the Niagara Group known as the Dayton limestone or "marble" approaches within a few feet of the surface of the ground, and hence gives rare opportunities for good and readily worked quarries.

Allen's Quarry.

Several years ago, shortly after the construction of the Cincinnati Northern railroad, a quarry was opened on the farm of John E. Allen, about a half a mile east of Centreville. This quarry is probably the most easily worked and most accessible (for purposes of transportation) in the county. The Clinton rock is here of a pinkish or often dirty white color. It is exposed only by the removal of the overlying Niagara stone, or by the cutting of ditches. Yet many and often rare fossils have been found here. *Orthis Daytonensis*, with both valves preserved, has been discovered. A thin seam of bluish clay, between the Clinton and Niagara stone, furnished the large *Calymene*, to be described later. This clayey layer has not yet shown any of the curious little fossils found in the marl at Huffman's Quarry, although apparently its stratigraphical equivalent.

Beginning with the base of the Niagara exposure, the courses of Dayton stone run as follows: a 16, 18½, 6, 3½, 2¾, 4, 4¾, 2¼, 4¼ and a 1¼ in. course. Comparing these courses with those at Huffman's Quarry, it will be noticed that the 16 in. course corresponds to the 20 in. course of that quarry, and like it is divided into smaller layers: in this case into a 4 in. layer below and a 1½ in. layer above, the intermediate divisions, if any, not having been noted. The 18½ in. and 6 in. layers also correspond very nicely to the equivalent divisions of the 26 in. layer in the other quarry; and the 3½ in. and 2¾ in. layers might be combined so as to correspond to the 7 in. layer. Above this point comparisons would perhaps prove treacherous. Above the Dayton stone proper are found shaly layers, 50 in. and 9 in. thick, which do not sufficiently approach the crystalline character of the Dayton stone to be classed with it.

MISCELLANEOUS QUARRIES.

In addition to the quarries just mentioned, one or two others are worthy of at least a slight reference in this paper.

Fauver's Quarry.

About two miles north of Dayton, some distance west of the Covington pike, is a quarry which displays both the Clinton and Niagara groups. The quarry presents some peculiar features which will be made a special object of investigation for the next paper. The Clinton ends above in a layer of blue clay, succeeded by a number of courses of Dayton limestone, none of which attain any great thickness. The blue clay layer, besides the usual fossils of the Clinton Group, has also furnished a specimen of *Eichwaldia reticulata*, Mr. E. M. Thresher being the collector.

Fair Haven Quarry.

In Preble county, half a mile north of the village of Fair Haven, in a stream entering Four Mile Creek, a quarry has been opened, giving an exposure of the Clinton. Here there have been found numerous corals so far not known elsewhere in this State, and also the usual Clinton forms. Among others, a form of *Clathropora Clintonensis*, with unusually large oval openings (passing entirely through the bryozoum and thus forming the branches of the reticulations,) deserves special mention. A species of *Ptychophyllum*, in a fine state of preservation, occurs here; a similar, if not identical form, being found at Allen's Quarry. The exposure does not give a complete section, but over four feet of the Clinton Group are exposed.

About two miles north, along Four Mile Creek, another quarry has exposed the higher strata of the Niagara group. Its peculiar feature is a seam of cherty limestone, about nine inches thick, containing *Atrypa reticularis* in well preserved specimens. No other fossils have so far been noticed.

PALEONTOLOGY.

The Clinton Limestone of Ohio is very fossiliferous. The fossils, however, are often difficult to obtain on account of the hardness of the rock and its irregular fracture, when submitted to the blows of a geologist's hammer. For the same reasons the identification of gasteropods becomes extremely difficult, since their apertures are scarcely ever seen. In one form alone are they of common occurence, *Cyclonema bilix;* this fossil is of rather frequent occurrence in the upper, shaly part of the group, from which it sometimes weathers with the neatness of Lower Silurian fossils in this State. Some forms of brachiopods preserve their outlines very indistinctly. This is true of *Orthis flabella* and the small form I have ventured to call *O. elegantula, var. parva.* Others are found only as single valves firmly held by the rock so that only one face, the external or internal, is presented. On this account it is difficult to associate dorsal with ventral valves, internal with external features. A few forms, however, occurring in the higher, more shaly strata, are frequently found well preserved, with both valves connected. Such are *Orthis hybrida*, *O. elegantula*, and *Rhynchonella scobina.* *O. biforata f. Clintonensis* and *Triplesia Ortoni* most frequently are found as fragments embracing that portion of the valves surrounding the beaks; these fragments show both the external and internal features. They are also, although not as frequently, found as entire shells, with both valves united. *Eichwaldia reticulata*, *Orthis fausta*, and *Meristella umbonata*, the last from the middle of the formation, have all been found as entire shells. The trilobites are usually found as fragments, the heads and tails being disconnected. In *Illænus* the movable cheeks and glabellæ are thus found separated. In only one specimen of *Dalmanites Werthneri* the intermediate articulations of the thorax were discovered. The association of glabellæ and pygidia, therefore, is somewhat difficult. Still with all these failings, the fossilized forms of the Clinton Group deserve careful study, and to the careful and painstaking collector they will form one of the most productive fields of labor in the State.

The fossils of the Clinton Group differ from the remains of the superposed Niagara formations of the State in this important particular, that, whereas the latter are most frequently found in the form of casts, the former almost always present the external features. Hence they are more readily determined and their structure can usually be easily studied by means of microscopic sections. In the following pages a full account will be given of the *Brachiopoda* and *Lamellibranchiata* of the group, as far as studied. To this are appended partial accounts of the *Gasteropoda* and *Trilobita* of the same. The next paper will contain a continuation of the account of the latter groups, with a study of the bryozoans and corals of the group. The latter present a few features of special importance in the identification of the stratigraphical relations of this group.

Great pains have been taken in the identification of specific forms, and new species have been formed only with reluctance, and when there seemed to be an absolute necessity for such a course. Nevertheless quite a large number managed to creep in. Of these the most interesting are the series of forms which have so far seemed characteristic of that portion of the Clinton Group, here called the Beavertown marl. They are to be specially noticed for their small size, being accompanied with only a few larger species.

If the writer has anywhere been deceived in his judgment, he would be glad to receive such information as would be useful in correcting the same, since upon the correctness of the identification of the fossil forms must depend the correctness of all discussions as to the stratigraphical relations of the Clinton Group of Ohio.

In the description of fossil forms the nomenclature used by Hall and Meek has been adopted, and where species are identified with, or described as closely related to forms already published by these or other authors, the description of Ohio forms has been as far as possible adapted to the original description. However, no statement has been repeated which is not fully vouched for by specimens on hand, and conformity means only an acknowledgement of the excellence of the descriptions taken as a model.

Most of the species described in this paper may be found in the writer's private collection. Valuable assistance, however, has been afforded by numerous friends, both in the loan of specimens and books, as well as in such general information as has proved valuable from time to time. Among others, the writer feels specially indebted to Mr. E. M. Thresher and Mr. Geo. Caswell, of Dayton—both active collectors of the Clinton fossils near that city. He also wishes to express his appreciation of the kindness and interest shown him by Prof. Edward Orton, of the Ohio Geological Survey, a man of eminent ability, and whose careful, painstaking work has justly won him a place among the most honored of American geologists.

BRACHIOPODA.

I.	Leptæna prolongata,	n. sp.
II.	Strophomena patenta,	Hall.
III.	— rhomboidalis,	Wilckens.
IV.	Orthis biforata, var. lynx. f. reversata.	
V.	— biforata, var. lynx. f. Daytonensis.	
VI.	— flabella,	Sowerby.
VII.	— hybrida,	Sowerby.
VIII.	— elegantula,	Dalman.
IX.	— elegantula, var. parva,	n. var.
X.	— fausta,	n. sp.
XI.	— Daytonensis,	n. sp.
XII.	Meristella umbonata,	Billings.
XIII.	Triplesia Ortoni,	Meek.
XIV.	———triplesiana,	n. sp.
XV.	Rhynchonella scobina,	Meek.
XVI.	Zygospira modesta,	Hall.
XVII.	Atrypa nodostriata,	Hall.
XVIII.	Eichwaldia reticulata,	Hall.

The Brachiopoda of the Clinton Group of Ohio seem to have their nearest relatives in the Niagara formations of other States. *Eichwaldia reticulata* is characteristic of the Waldron beds of Indiana. *Orthis hybrida* and *O. elegantula* are widely distributed Niagara forms. *Orthis flabella* and *Atrypa nodostriata* recall the Niagara fossils of New York. *Rhynchonella scobina* is closely related to *R. neglecta*, a Niagara fossil of considerable distribution. *Leptæna prolongata* recalls *L. transversalis* of New York. *Orthis fausta* finds its nearest relative, perhaps, in *O. Nisis*, of Kentucky strata, equivalent to Niagara formations. *Meristella umbonata* is found in the Middle Silurian of Anticosta. *Strophomena patenta*, however, is found in New York, in rocks undoubtedly Clinton. Three species, *Strophomena rhomboidalis*, *Orthis biforata var. lynx*, and apparently also *Zygospira modesta* extend from the Lower Silurian into the Clinton rocks of Ohio.

Of these, *Strophomena rhomboidalis* and *Orthis biforata*, *var. lynx*, have a great range vertically. *Strophomena patenta* differs from the New York types of this species in the finer and more numerous radiating striæ. *Zygospira modesta*, as stated, has its relations in lower strata. The testimony of the other fossils seems to be more or less decidedly in favor of a relationship with Niagara forms.

GENUS LEPTÆNA, Dalman.

I. LEPTÆNA PROLONGATA, *sp. n.*

(*Plate XIII, Figs.* 5 *a, b.*)

Shell of medium size, concavo-convex, semi-oval; hinge line prolonged, exceeding the width of the shell, lateral extremities acutely angular.

Ventral valve alone known, very convex, highest elevation at about one third the distance from the beak to the anterior margin, thence curving rapidly towards the anterior margin, and far more so towards the posterior margin or hinge line, which is inflected. There is a tendency towards a slight mesial elevation.

Surface marked by fine, close striæ, some of which are more prominent, the spaces between being puncto-striate. Interior of shell also striated in the same direction as the exterior surface, the reticulated structure of *L. transversalis* not observed.

This species is closely related to *L. transversalis*, from which it differs in its larger size, the lateral prolongation of the shell, especially along the hinge line, absence as far as known of reticulations among the interior striæ, and by the tendency towards a mesial fold. From *L. sericea* it can be distinguished by its great convexity from the anterior towards the posterior regions. (The specific term is intended to suggest the lateral prolongation of the shell.)

Length, 13 mm.; breadth, 25 mm.; convexity of the ventral valve, 5 to 6 mm.

Locality and position. Soldiers' Home, Clinton Group.

GENUS STROPHOMENA. Rafinesque.

II. STROPHOMENA PATENTA, Hall.

Shell described in Ohio Pal. Vol. II.

Locality and position. Soldiers' Home Quarries, Clinton Group: common.

III. STROPHOMENA RHOMBOIDALIS, Wilckens (sp.).

Described in Ohio Pal. Vol. II.; variable.

Locality and position. Soldiers' Home and Huffman Quarries, Clinton Group.

GENUS ORTHIS, Dalman.

ORTHIS BIFORATA, var. LYNX, *Von. Buch.*

IV. forma *reversata.*

(*Plate XIII, Fig.* 7.)

Shell of the type known as var. *lynx*, especially those forms which show a greater number of plications on the mesial fold and in the sinus. The name given to the form here described is expected to have only a local use to distinguish it from the variety *lynx*, as described and figured in the Ohio Geological Reports from the strata of the Cincinnati formations. Typical specimens of the different varieties of *O. biforata* from the Lower Silurian formations of Ohio have an odd number of plications in the mesial sinus, and an even number on the mesial fold. Thus var. *lynx* has typically three in the sinus and four on the fold. When more than this number appear, the typical plications are the stronger. Typical specimens of *O. biforata* var. *lynx* in the Upper Silurian formations (Clinton Group), in the two forms known to me, have an even number of plications in the mesial sinus, and an odd number on the mesial fold. In the form *reversata* the plications branch frequently, but the typical arrangement remains clearly defined. Although these distinctions are not expected to be of value elsewhere, they are too well defined and of too much interest in our local formations, not to be noted.

Shell attaining a fair size, the dorsal valve a little larger; shell wider than long, with a sub-graduate outline; no very gibbous forms have as yet been found; hinge line less than the greatest breadth of the valves; cardinal extremities obtusely angular; lateral margins rather sinuous near the hinge line, rounding to the front, where it is somewhat sinuously rounded at the junction of the mesial sinus and fold. Beaks nearly equal, incurved and approximate, sometimes almost touching; cardinal areas nearly equal.

Dorsal valve more convex than the ventral, its greatest convexity being near the middle. Mesial fold rather rounded, arising near the beak, becoming more prominent as it extends forward, with rounded sides; beak projecting beyond the hinge margin, strongly incurved; cardinal area directed backward, somewhat incurved. Foramen broad, triangular and not closed by the cardinal process.

Ventral valve with a mesial sinus, beginning near the beak, extending forward, terminating in a rounded projection which continues the curvature of the shell and thus produces a sinuous outline for the front edge of the shell. Surface of the valve rounded into the moderately concave sinus. Beak less strongly incurved than that of the dorsal valve. Cardinal area incurved and directed backward, less, however, than that of the other valve. Foramen triangular, wider than high; hinge teeth moderately prominent and trigonal; muscular cavity oblong, little more than one third the length of the shell, lateral margins parallel, well defined by the dental ridges. On either side of this cavity are a number of short striæ, which are arranged in longitudinal lines following about the direction of the plications.

Surface of each valve with rounded, radiating plications, from 24 to 36 in number, of which four to six occupy the mesial sinus, and five to seven (in one specimen ten or eleven) the mesial fold. In the sinus two plications begin at the beak, two additional ones are immediately added, and later one or two more at one third or one half the length of the shell from the beak. On the mesial fold three plications originate at the beak, to which two more are added at one fourth the length of the shell from the beak; later two more appear and in one specimen in hand ten or eleven plications are more or less distinctly shown. The plications in the sinus and on the fold branch in all specimens as described above; the lateral ones, 10-15 in number, are almost always simple. Lines of growth not shown in the specimens found. Well preserved specimens under the microscope show numerous minute granules, arranged in regular rows across the plications.

Length of the specimen figured, 24 mm.; breadth, 28 mm.; hinge line, 21 mm.; convexity, 18 mm.; breadth of largest specimen, 37 mm. Comparing this description with that given by Meek, in Pal. Ohio, Vol. I., it will be found to be about the same as that of var. *lynx*. (The name of the form is intended to suggest the fact that the odd and even number of mesial plications are found on valves opposite to those on which they occur in Lower Silurian forms, as though the shell had been *turned about.*)

Locality and position. Throughout the Clinton Group. Found entire in the Beavertown marl, generally in fragments in the rest of the group. Soldiers' Home, Centreville, Huffman's Quarries.

It may be interesting to notice in this connection that all the forms of *Orthis biforata* from the upper Niagara formations of Ohio, which I have seen, belong to a smaller type of the var. *lynx*, and are characterized, like our Clinton specimens, by an even number of plications in the sinus, and odd number on the mesial fold.

V. Forma *Daytonensis*.

(*Plate XIII, Fig.* 8.)

This is another form belonging to the forms typified by the varieties of *O. biforata*, found in the Cincinnati formations. They bear considerable resemblance to the young of var. *lynx*, and in one case, having the hinge line greater than the breadth of the shell, it varies somewhat in the direction of var. *acutilirata*. The name is expected to have only a local use for the Clinton forms which have two plications in the mesial sinus, and three simple ones on the fold, all of which seem to originate at about the same distance from the beak.

Shell of small size, wider than long, with a subquadrate outline, hinge line usually shorter than or equaling the breadth of the valve, in one specimen exceeding it in size. The shells have their outline indistinctly preserved and are found only as single valves showing their exteror surface.

Ventral and dorsal valves with sinus and fold rounded, the plications also more rounded than those of Lower Silurian formations, simple.

These specimens could perhaps be considered as the young of the form *reversata*, were it not for the simple plications on both fold and sinus, which remain simple where on the corresponding places of the other form there would be several additional plications intercalated.

Length of medium sized specimen, 12 mm.; breadth, 18 mm.; convexity, as well as can be determined by a comparison of different single valves, 9 mm. Breadth of largest specimen, 24 mm. (The name of the form is taken from the locality where it is most frequent.

Locality and position. Soldiers' Home, Clinton Group.

VI. ORTHIS FLABELLA, *Sowerby*.

(*Plate XIII, Figs.* 12 *a, b.*)

Shell semi-oval ; hinge line equal to the breadth of the valve or generally a little less. Shell wider than long, the dorsal valve much more convex than the other, very variable.

Dorsal valve very convex, the greatest convexity being near the beak ; beak much elevated, incurved.

Ventral valve flattened, with a shallow mesial sinus, more marked along the posterior half of the shell, towards the beak; beak but slightly elevated.

Surface marked by twenty to twenty-four simple, strong, low, rounded, almost straight plications, equal to the broad, flattish spaces between them in width.

From the form as described above there are many variations. The middle plication of the dorsal valve frequently manifests a tendency towards becoming more elevated and almost forming a low carina towards the beak; the other plications becoming more indistinct as they approach this point. They may also become more angular, more numerous, approaching thirty in number, and the spaces between them may become even narrower than the plications. Again, in a few specimens they divide dichotomously towards their extremities. The shells also vary considerably in size, from 18 to 43 mm. in breadth. Faint concentric striæ may also appear in the depression between the plications; lines of growth are still more rare. The anterior and lateral margins of the shell are rarely well defined in our specimens.

Length, 18 mm.; breadth, 26 mm.; convexity, as nearly as can be determined by comparison of the separated valves, 8 to 9 mm., being accounted for mainly by the great convexity of the dorsal valve.

The shell has been found only in the form of separated valves, the exterior surface exposed, the cardinal area invisible; however, the few simple plications usually equaling the flat depressions between sufficiently determine this species.

Locality and position. Soldiers' Home Quarries, Clinton Group; very common in places.

VII. ORTHIS HYBRIDA, *Sowerby*.

(*Plate XIII, Figs.* 10 *a*, *b*.)

Shell lenticular, greatest diameter at one third the length of the shell from the beak, wider than long; valves nearly equal, hinge line about half the width of the shell.

Dorsal valve convex, evenly rounded, beak less elevated than that of the ventral valve, cardinal area smaller, extending the length of the hinge line.

Ventral valve convex, with a broad, undefined depression extending from near the centre to the anterior margin; beak a little incurved, cardinal area directed backwards, incurved. Owing to the depression along the anterior portion of the ventral valve, the shell has a sinuous outline in front.

Surface marked by fine, close, branching striæ, which are arched upwards along the postero-lateral margins; radiating striæ crossed by several lines of growth. Concentric striæ not distinguishable in the specimens at hand.

Length, 17 mm.; breadth, 19 mm.; convexity, 8 mm.; hinge line, 10 mm.

Locality and position. Soldiers' Home Quarry, in the upper, shaly courses of the Clinton Group.

VIII. ORTHIS ELEGANTULA, *Dalman.*

(*Plate XIII, Figs.* 11 *a, b.*)

Shell semi-oval; hinge line shorter than the width of the shell, exceeding the length of the cardinal area.

Dorsal valve almost flat, with a shallow depression extending from the beak to the anterior margin; more marked near the beak; beak not incurved.

Ventral valve convex, extremely elevated towards the beak; beak much exceeding that of ventral valve in length, and incurved over the cardinal area.

Surface marked by fine radiating striæ, branching, curved upwards along the lateral and posterior margins; crossed by lines of growth, and fainter concentric striæ.

This species may be readily distinguished from *O. hybrida* by the flat dorsal valve, and shallow depression extending from the beak to the anterior margin, also by the more quadrangular outline of the shell.

Length, 16 mm.; breadth, 17 mm.; convexity, 4 mm.; hinge line, 10 mm.

Locality and position. Soldiers' Home and Centreville Quarries, in the upper courses of the Clinton Group.

IX. var. *parva*, or young.

(*Plate XIII, Figs.* 17 *a, b.*)

Among the specimens of *Orthis* collected at the Soldiers' Home Quarries occur great numbers of a small form resembling *O. elegantula*. The ventral valve is exceedingly convex and the surface is marked by fine, numerous, indistinctly preserved striæ, being plainest at the lateral and anterior margins of the valve. The beak is very prominent and incurved.

An ordinary sized specimen of the ventral valve measured gave a length of 6 mm.; breadth, 7 mm.; convexity, 3 mm. The largest specimen observed does not exceed 10 mm. in breadth.

The variety occurs frequently in the limestone of the Clinton Group, whereas the species described above seems confined to the upper, shaly courses. The main reasons for separating it from the species are its smaller size, greater convexity, and different location. If not the young of *O. elegantula* it is certainly a well marked variety. Its general appearance is somewhat like that of *O. pisa* of New York strata, but our shell does not have both valves connected and the presence of an occasional dorsal valve having a low mesial depression, apparently to be associated with the ventral forms, would preclude such a determination. For the present it may be considered a variety of *O. elegantula*.

Locality and position. Widely distributed throughout the Soldiers' Home Quarries, in all except the uppermost layers of the Clinton Group.

X. ORTHIS FAUSTA, *sp. n.*

(*Plate XIII, Figs.* 15 *a, b, c, d*; *and Figs.* 16 *a, b.*)

Shell of medium size or often less, wider than long; hinge line not equaling the width of the shell; lateral margins rounded in front, posteriorly incurved, frequently expanding at the hinge line just enough to leave the postero-lateral margins extend a slight distance beyond the incurved portion of the same, like little ears. Convexity of the valves almost equal, that of the ventral valve being slightly the greater.

Dorsal valve convex, with a distinct mesial sinus extending from the beak to a point about one third the distance from the anterior margin, where it vanishes; the greatest convexity lies a little behind the middle, on either side of the mesial sinus. Beak slightly elevated, scarcely incurved; foramen broad-triangular, width equal to twice the height. Cardinal process small, laterally compressed, not filling the foramen, in a line with the base of the cardinal area; cardinal area moderate, one third that of the ventral valve, equaling the hinge line, directed backwards, arched. Postero-lateral regions of the valve moderately compressed.

Ventral valve more convex, its greatest convexity about two-fifths the distance from the beak, sloping regularly to the lateral and anterior margins. Beak prominent, incurved, having two or three times the elevation of the dorsal valve; cardinal area corresponding, directed obliquely backwards, arched; foramen triangular.

Surface marked by 40 to 50 radiating striæ, which increase by frequent intercalations, and are crossed by distinct concentric striæ, giving the surface a beautifully ornate appearance, which will serve to readily distinguish it from the other species of *Orthis* found here. (Figs. 15 *a*, *b*, *c*, *d*.)

A form of this species occurs having the general shape and characteristics of the typical specimens, but the plications are more angular, sometimes almost acutely ridged, and crossed by concentric striæ, more closely arranged, and also much less distinct, not producing the ornate appearance characteristic of the typical form. For this reason I was once inclined to separate them under a different name, *acutoplicata*, but at present I am of the opinion that they are not sufficiently distinct to be placed even under a varietal name. (Fig. 16 *a*, *b*.)

Length of a specimen, 17 mm.; breadth, 21 mm.; convexity, 9 mm.; varying from this to specimens with a convexity of only 6 or 7 mm.

This species seems to be a form intermediate between *Orthis insculpta* and *O. bella-rugosa* of the Lower Silurian strata, and *O. Nisis* of the Niagara group of Kentucky. It differs from the last in the much smaller elevation of the ventral beak; from the second, in the coarser and broader appearance of its radiating striæ, the absence of an incurved anterior margin, and by the greater curve of its ventral beak; from the first it is chiefly distinguished by greater size and more numerous striæ.

Locality and position. Soldiers' Home Quarries, Clinton Group; the typical forms, in the upper part of the group; the variety with more acute plications, in the lower portions of the same.

XI. ORTHIS DAYTONENSIS, *sp. n.*

(*Plate XIII, Figs.* 13 *a, b, c, d.; Figs.* 20 *a, b; and Fig.* 21.)

Dorsal valve wider than long, very convex, greatest convexity being just behind the middle, thence sloping almost equally on all sides, except toward the postero-lateral regions, which are somewhat compressed; a faint mesial sinus towards the beak. Cardinal area narrow, foramen broadly triangular, cardinal process narrow, compressed laterally, and situated beyond a line connecting the lower edges of the cardinal area, or on the line itself; not filling the foramen.

Ventral valve flattish, its greatest convexity one fourth the distance from the beak or even closer; thence sloping towards the postero-lateral extremities and the anterior margin, causing the anterior portion of the valve to be depressed, and leaving that portion of the shell extending from the beak to about the middle of the lateral margins elevated above the other portions of the valve.

The interior of a ventral valve found will be sufficiently explained by Fig. 20 b, of Plate XIII. A single specimen with both valves united has been found presenting the characteristics of the valves just described, and furnishes my authority for uniting them under the same species. But as a curious matter of fact most of the ventral valves have been found at Allen's Quarry, and all the dorsal valves at the Soldiers' Home Quarries. The entire specimen is smaller in size than most of the single valves found.

Surface marked by 60 to 90 fine, radiating striæ; the branching is frequent and by intercalations. Concentric striæ distant from each other about the space between the radiating striæ, or more, giving sometimes the appearance of quadrangular punctæ between the striæ; concentric striæ usually best preserved in the spaces between the radiating striæ, often not very plain on the striæ themselves.

Length of a dorsal valve, 17 mm.; breadth, 21 mm.; convexity, 5 to 6 mm. Length of a ventral valve, 21 mm.; breadth, 26 mm.; convexity, 4 to 5 mm. Length of the only complete shell found, 18 mm.; breadth 23 mm.; convexity, 8 mm.; the relative elevation of the beaks in this specimen may be understood by examining Fig. 21, of Plate XIII.

Locality and position. Allen's and Soldiers' Home Quarries, Clinton Group.

GENUS MERISTELLA, Hall.

XII. MERISTELLA UMBONATA, *Billings* (sp.).

(*Plate XIII, Figs.* 2 *a, b.*)

Shell elongate ovate, the sides forming a continuous curve from the umbo of the ventral valve to the front margin, with the exception of a very slight inward curve at the hinge extremities, not at all resembling those of the Ohio forms of *M. cylindrica;* front margin rounded.

Dorsal valve convex, greatest elevation at one third the distance from the beak, thence obtusely rounded towards the beak which is concealed by that of the ventral valve.

Ventral valve strongly convex, forming a continuous curve from the anterior margin to the beak, which is spirally incurved upon the beak of the dorsal valve, which it more or less conceals. The ventral valve considerably elevated above the beak of the dorsal, more so than would be indicated by the figures accompanying this description.

Surface smooth, the concentric striæ indistinct.

Length of dorsal valve, 14 mm.; of ventral valve in the same specimen, 17 mm.; breadth, 14 mm.; convexity, 12 mm. Length of dorsal valve in a small specimen, 10 mm.; ventral valve, 12 mm.; breadth, 8 mm.; convexity, 8 mm.

The first inclination was to place these specimens under *Meristella cylindrica*, but several reasons will not permit this: the size of the specimens is smaller, the elevation of the ventral valve is greater, the length of the shell is relatively smaller as compared with its breadth, and considered as young of *M. cylindrica*, their convexity is too great. On the other hand they are of the same size and outline as *M. umbonata*. Associated with the ordinary forms are also separated valves, broadly ovate in outline and more nearly resembling those forms described by Billings under the specific term *Prinstana*. Since the writer is of the opinion that this species is only another form of *M. umbonata*, its apparent occurrence in the same strata in Ohio with the form just described, seems to him an additional proof of its identity.

Locality and position. Soldiers' Home Quarry, Clinton Limestone. Specimens from this locality were kindly loaned by Mr. George Caswell, of Dayton.

GENUS TRIPLESIA, Hall.

XIII. TRIPLESIA ORTONI, *Meek*.

Described in Ohio Pal. Vol. I.

Locality and position. Soldiers' Home and Centreville Quarries, Clinton Group; the upper "shovel ends" are frequent in the upper shaly courses of the Group.

GENUS ———

XIV. ——— TRIPLESIANA, sp. n.

(*Plate XIV, Figs.* 13 *a, b; and Fig.* 14.)

The generic relations of the following shell I have been unable to determine satisfactorily, although the specimens are in a moderately good state of preservation. A specific name is merely suggested for the local use of collectors, and a description appended to give notification of at least the existence of such a shell. The specific name is intended to suggest its similarity in appearance to certain very flat forms of *Triplesia Ortoni* in which the cardinal area is not much developed.

Shell subquadrate, or rounded anteriorly and more oval in outline, medium or larger in size; cardinal area scarcely developed, very narrow, but apparently equalling the hinge line. Beaks approximate, with about the same elevation, scarcely elevated above the hinge line, not prominent.

One valve of the shell has a low mesial elevation of moderate breadth, corresponding to a mesial sinus on the other valve, which is shallow but equally distinct. The comparative breadth of the mesial fold and sinus, considering the general contour of the shell, although suggesting *Triplesia Ortoni*, is dissimilar. In other respects it suggests to me a strophomenoid shell.

Surface marked by broad, radiating, scarcely evident folds, and similar concentric elevations of growth, in addition to which, very fine, fibrous, radiating striæ are visible in the more or less silicified shell. Lateral margin meeting the hinge line at little more than an angle of ninety degrees, rounded anteriorly, slightly projecting at the middle.

Length, 27 mm.; breadth, 29 mm.; convexity, 12 mm. Length of another individual, 28 mm.; breadth, 30 mm.

Locality and position. Soldiers' Home Quarry, in the middle of the Clinton Group.

GENUS RHYNCHONELLA, Fisher.

XV. RHYNCHONELLA SCOBINA, *Meek.*

Described in Ohio Pal. Vol. I and II.

Locality and position. Soldiers' Home, Huffman, and Centreville Quarries, Clinton Group; common.

GENUS ZYGOSPIRA, Hall.

XVI. ZYGOSPIRA MODESTA, *Say (sp.).*

(*Plate XIII, Fig.* 6.)

Described in Ohio Pal. Vol. I., and mentioned as occurring in the Clinton Group. I have seen no specimens which could be referred without doubt to this species unless it be a dorsal valve of the following description.

Dorsal valve subquadrate orbicular; beak not elevated; marked by about twenty simple plications; with a shallow mesial sinus, occupied by three plications, the middle plication larger, the lateral ones smaller than the plications immediately adjacent.

Length, 7 mm.; width scarcely larger.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group.

GENUS ATRYPA, Dalman.

XVII. ATRYPA NODOSTRIATA, *Hall.*

(*Plate XIII, Fig.* 9.)

Shell described in Ohio Pal. Vol. II.

A small species of Atrypa referred here occurs sparingly, of the following description.

Shell oval, marked by plications, branching near the middle of the shell. Mesial sinus on the ventral valve plainly defined by the bordering plication on each side, containing three to five plications. Dorsal valve with mesial elevation, well defined by a more or less sharp sinus on each side, which is more marked towards the beak.

Length, 11 mm.; breadth, 11 mm.; convexity, 6 mm.

Locality and position. Soldiers' Home, Clinton Group.

GENUS EICHWALDIA, Billings.

XVIII. EICHWALDIA RETICULATA, *Hall.*

(*Plate XIII, Figs.* 4 *a, b.*)

Shell broadly triangular ovate, gibbous, cardinal slopes flattened.

Ventral beak small, acute, flattened on the back, closely incurved, the sinus extending from the beak to the anterior edge, broad, distinct.

Dorsal valve more convex, beak obtuse, strongly incurved, a low, fairly defined mesial fold extending from the beak to the anterior margin.

Surface covered by fine, hexagonal, reticulate markings, largest along the antero-lateral slopes, and decreasing in size towards the sinus and posterior regions. A small space near the ventral beak is destitute of markings.

Length, 8 mm.; breadth, 8 mm.; convexity, 6 mm.

Locality and position. Fauvers' Quarry north of Dayton, Clinton Group. Collection of Mr. E. M. Thresher.

LAMELLIBRANCHIATA.

I.	Pterinea brisa, - - - - -	Hall.
II.	Grammysia Caswelli, - - - -	n. sp.
III.	Cypricardites ferrugineum -	Hall and Whitfield.
IV.	Nucula minima, - - - - - -	n. sp.

The *Lamellibranchiata* of the Clinton Group of Ohio are but few both in the number of species and in the frequency of their occurrence. *Pterinea brisa*, if correctly identified, adds another link connecting this formation with the Niagara Group of the West. It occurs also at Waldron, Indiana, and Bridgeport, Illinois.

GENUS PTERINEA, Goldfuss.

I. PTERINEA BRISA, *Hall.*

(*Plate XIII. Figs.* 14 *a, b.*)

Left valve alone found. Body of the shell obliquely sub-ovate, extremely inequilateral; anterior wing moderately extended; sinuate at its junction with the body; posterior wing acutely extended a little beyond the posterior extremity of the shell; umbo prominent, beak rising a little above the hinge line, muscular impression in right valve unknown from want of specimens.

Surface marked by strong, radiating striæ, and less conspicuous concentric striæ.

The intercalation of radiating striæ in some cases gives rise to an appearance similar to the dentations and groovings figured in the Indiana reports, but not identical with them. The concentric striæ also are not so prominent. The crystallized character of our specimens will, perhaps, account in part for these discrepancies. Fig. 14 *b* represents a specimen with fewer radiating striæ, referred here.

Length, 16-17 mm.; height, 10-11 mm.; convexity of the left valve, about 2 mm.

Locality and position. Soldiers' Home Quarries, Clinton Group.

GENUS GRAMMYSIA, De Verneuil.

II. GRAMMYSIA CASWELLI, *sp. n.*

(*Plate XIV, Figs.* 12 *a, b.*)

Shell small, transversely sub-ovate; umbonal regions gibbous, anterior regions likewise; height at the beaks equalling about five-eights of the length. Anterior end sloping abruptly from the beaks above, with a distinctly concave outline, to the lower end of the lunule, where it is met by the rounding base, forming more or less an angle at their junction; base forming a broad semi-elliptic curve; posterior end more compressed, the specimen at hand being too imperfect to determine whether it gaps at this extremity, although it is presumed to do so a little from the curvature of the better preserved valve; posterior end rounded, then curving upward and quite rapidly forward almost merging into the hinge line.

Cardinal margin indistinctly preserved, judged to be nearly horizontal, slightly concave in outline, and inflected along its entire length, forming a well defined escutcheon; lunule distinct, with an ob-ovate outline, quite deep. Beaks prominent, strongly incurved, obliquely to the hinge, directed a little forwards, posterior umbonal slopes prominently, yet rather broadly rounded.

Surface ornamented in the cast by well-defined concentric ridges and furrows, these in the specimen at hand crossed by fine parallel lines, almost vertical, directed a little backwards, and which may be accidental rather than a special feature of the shell. Ridges strongest anteriorly, becoming less distinct posteriorly. A portion of the shell where preserved shows the ridges far less defined than on the cast.

Length, 37 mm.; height, 25 mm.; convexity, 25 mm.

Locality and position. Soldiers' Home, Clinton Group. Collection of Mr. Geo. Caswell.

GENUS CYPRIGARDITES, Conrad.

III. CYPRICARDITES FERRUGINEUM, *Hall and Whitfield.*

Species described in Ohio Pal. Vol. II.

Locality and position. Wilmington, Clinton County, Ohio, Clinton Group. To my knowledge not found elsewhere.

GENUS NUCULA, Lamarck.

IV. NUCULA MINIMA, *sp. n.*

(*Plate XIV, Figs.* 8 *a, b, c.*)

Shell (presumably the cast) very small, ovoid, gibbous above the middle towards the beaks, outline curving to the base and posterior extremity, anteriorly curving more rapidly to the beaks above. Beaks, near the anterior extremity of the shell, incurved and inclined forwards. Hinge line at one-third the distance from the beak to its posterior extremity supplied on each side with a narrow fold, directed backwards, making a small angle with the hinge line, and vanishing at one-third the distance from the posterior extremity in the depressed regions formed by the raised postero-umbonal regions.

Near the beak on each valve are three to four radiating grooves, which are characteristic of this species and are evident under the microscope.

In addition to these grooves are three more or less clearly defined pits, one being placed in the anterior groove near the beak, and the two others in the second groove, one on each side, and at a greater distance from the beak. Along the hinge line, anterior to the beaks, are two or three more or less distinct crenulations, which appear a little like plications originating in the lunule near the beak and becoming more distinct at the hinge line.

Length, 2 mm.; height, 1.4 mm.; convexity, 1 mm.

Locality and position. Beavertown marl, Huffman's Quarry; not found elsewhere in the Clinton Group. Associated with many other minute forms, apparently chiefly in the form of casts, among these a number of *gasteropoda*.

GASTEROPODA.

I.	Cyclonema bilix,	Conrad (sp.).
II.	Trochonema nana,	n. sp.
III.	Raphistoma affinis,	n. sp.
IV.	Pleurotomaria inexpectans,	Hall and Whitfield.
V.	Cyclora alta,	n. sp.
VI.	Strophostylus cyclostomus,	Hall.
VII.	Platyostoma Niagarense,	Hall.
VIII.	Bucania exigua,	n. sp.
IX.	Bellerophon fistello-striatus,	n. sp.

The *Gasteropoda* of the Clinton Group, identified with previously described forms, are too few to form any great basis of comparison, stratigraphically. *Cyclonema bilix* ranges from the Lower Silurian into the Upper. *Strophostylus cyclostomus* is found also at Waldron, Indiana. *Platyostoma Niagarense* differs in size and expansion at the aperture from typical specimens, but its connection with them seems undoubted. At any rate its deviation from the typical forms is far less than the var. *trigonostoma* of Meek, and all these forms are typical of the Niagara.

GENUS CYCLONEMA, Hall.

I. CYCLONEMA BILIX, *Conrad* (sp.).

Shell described from the Lower Silurian in Ohio Pal. Vol. I.

Locality and position. Centreville and Soldiers' Home Quarries, frequent in the upper courses of the Clinton Group.

GENUS TROCHONEMA, Salter.

II. TROCHONEMA NANA, *sp. n.*

(*Plate XIV, Fig.* 16.)

Shell oblong, the height about twice the breadth, in the specimen figured the carina being a little more prominent than is there indicated. Volutions about three, increasing rapidly in size, the last disproportionately so, forming the larger bulk of the shell, almost equaling two-thirds the height. Shell thin; it is impossible to trace the suture line, but there is a carina where the volutions may be supposed to meet, this carina is distinctly grooved along the latter half of the last volution where it approaches the aperture of the shell; above the carina is a low shallow groove which in the last volution spreads so as to cover the entire volution. Surface smooth. Shell probably in the form of a cast.

Height, 3 mm.; breadth, 1.5 mm.; height of aperture, .9 mm. (?) breadth of aperture, .35 mm. (?) above, narrowing to .23 mm. (?) below. The measurements given for the aperture are liable to error, although there seem to be slight grooves and elevations at the close of the last volution, which look like an elongated aperture.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group. (Name signifying dwarf.)

GENUS RAPHISTOMA, Hall.

III. RAPHISTOMA AFFINIS, *sp. n.*

(*Plate XIV, Fig.* 18.)

Shell lenticular; breadth a little more than twice the height; convexity moderate above, equally so below; volutions varying from two and a half to three and a half, with a moderate slope above, coincident with that of the spire; the last volution sharply carinate around the periphery, convex below, being more so at the umbilicus into which the slope is abrupt; suture distinct, forming a small groove between the volutions; umbilicus as wide as the outer volution; the last volution becoming transversely rhomboidal, the aperture itself not being preserved, the breadth about three times the height. Surface apparently smooth.

This species is almost in every respect identical with forms of *R. lenticularis* as known to me from the Lower Silurian formations. It is however a much smaller shell, with less numerous volutions, and apparently a distinct form.

Breadth of largest specimen, 7 mm.; height, 3 mm.; breadth of the end of the last volution, 3 mm.; height, 1.2 mm.; aperture not preserved.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group. (Name signifying *related*, the shell being closely allied to the well known species, *R. lenticularis.*)

GENUS PLEUROTOMARIA, De France.

IV. PLEUROTOMARIA INEXPECTANS, *Hall and Whitfield.*

Shell described in Ohio Pal. Vol. II.

Locality and position. Iron ore beds of Clinton County, Clinton Group.

GENUS CYCLORA, Hall.

V. CYCLORA ALTA, *sp. n.*

(*Plate XIV, Figs.* 17 *a, b.*)

Shell very small, conoid subglobose; spire varying from two-thirds to slightly more than the diameter of the last volution; volutions three or four, increasing in size rapidly, but evenly; the last volution not so disproportionate in size to the rest of the shell as compared with the species so far described; suture deep; surface smooth; umbilicus small; aperture circular.

Height of largest specimen seen, 4 mm.; breadth, 3.5 mm. Height of a specimen of the usual size, 2 mm.; breadth, 2.75 mm. From this varying to specimens only 1 mm. broad.

This shell differs from the species of *Cyclora* so far described in its greater size, greater elevation of the spire, and the more regular increase of its volutions. Its general form approaches that of the closely related genus *Holopea.* Since the chief distinction, however, of the first genus is its diminutive size, it may be safe to refer to it also the specimens here described.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group; not scarce (Name intended to suggest the height of the spire, as compared with other species of this genus.)

GENUS STROPHOSTYLUS, Hall.

VI. STROPHOSTYLUS CYCLOSTOMUS, *Hall.*

(*Plate XIV. Fig.* 15)

Shell transversely broad-oval. Spire moderately elevated; volutions in the specimen figured, three, a fourth having broken away; the last volution by far the largest, ventricose. Aperture not fully exposed, oblique to the axis, subcircular.

Surface marked by shallow, broad striæ and closer, finer striations crossing the volutions obliquely and in a direction opposed to them.

Diameter of volutions, measured in a plane vertical to the shell and passing through the aperture, 6, 17, and 44 mm.; elevation of the second and third volutions less than half the last.

The character and direction of the shell aperture, the relative size and position of the volutions seem to leave no doubt as to the identity of the specimen, and will at the same time serve to distinguish it from any other species of gasteropod found in Ohio.

Locality and position. Soldiers' Home Quarry, Clinton Group.

GENUS PLATYOSTOMA, Conrad.

VII. PLATYOSTOMA NIAGARENSE, *Hall.*

(*Plate XIII, Figs.* 22 *a, b; and Figs.* 3 *a, b.*)

Shell ovoid, volutions three to four, the last much increased in size, spire elevated above the plane of the outer volution, about one sixth of the height of the shell.

Apex minute, expanding symmetrically as far as the outer volution, which is ventricose, and somewhat straightened at the aperture, so as not to maintain the curvature of the coil; in one specimen marked on the upper and lower side by a groove along which the striæ are abruptly bent; peristome undulated.

Surface marked by fine undulating striæ of growth, cancellated by finer revolving striæ.

The specimens referred here are smaller in size than typical forms of this species from western localities,and they differ from them in the tendency for the last volution to lessen its rate of curvature and become somewhat straightened as it approaches the aperture. This straightened appearance is in part due to the slight expansion of the lip at the aperture. Nevertheless these variances seem too slight to give rise to any separation from the typical form under a new specific name.

Height of shell, 21 mm.; elevation of the first three volutions above the plane of the last, 3.2 mm.; greatest diameter (passing through the aperture), 26 mm.; diameter vertical to the same, 17 mm.; diameter of the second and third coils, 2.6 and 7 mm.

Locality and position. Brown's Quarry, New Carlisle, Clinton Group, kindly loaned from the collections of the Ohio State University, by Prof. Edward Orton.

In the Soldiers' Home Quarries occur specimens which have usually been referred to *Holopea*, both by collectors and writers on geology. They consist for the most part of the upper three, or three and a half volutions of a shell which seems identical with the form just described. The character of the volutions and surface striations are the same; the last volution is also expanded at the aperture, giving greater distinctness to the lip, and having the same straightening effect on the curvature of the shell at this point.

In the New Carlisle specimens, however, the upper side of the last third of the last volution is flattened above and quite evenly rounded on the sides, forming in this way a line of elevation along the upper side of the volution, where the gradual curvature of the sides meets the flattened portion above. In the Soldiers' Home specimen which is best preserved, there is no flattening along the upper plane of this last volution, but instead, there is an even curvature from the suture to the lower side, an elevation being thus formed at the umbilicus into which the side of the lower third of the volution bends abruptly.

The aperture of this specimen, therefore, is oblique to a vertical diameter of the shell, whereas, in the New Carlisle specimens the aperture seems to have its greatest diameter vertical to the shell. Other forms, however, occur at the Soldiers' Home, among which are some with deep sutures and less oblique apertures; some quite similar to the New Carlisle specimens, but much smaller; a specimen with its coils arranged somewhat like *P. plebium*, but only half its size (Fig. 3 b.); and a specimen varying to the opposite extreme, with the last volution extremely ventricose, the upper volution only moderately raised, the part towards the aperture, however, being lacking (Fig. 3a). All the forms from the Soldiers' Home differ from the New Carlisle specimens, however, in their smaller size, the New Carlisle specimens differing in turn from the typical western forms chiefly in their smaller size. All these Clinton forms differ from the western in the slight expansion of the lip at the aperture and the straightened appearance of the volutions at this point, the rate of curvature decreasing.

Specimens last described, at Soldiers' Home Quarries, Clinton Group.

(The variations here indicated will be carefully figured in the next paper.)

GENUS BUCANIA, Hall.

VIII. BUCANIA EXIGUA, *sp. n.*

(*Plate XIII, Figs.* 18 *a, b, c, d.*)

Number of volutions not known, the last alone visible, increasing rapidly in size and expanding at the aperture; the exact character of the aperture not known from want of preservation, but is presumed to be similar to that of *B. bilobatus.* The outer volution rounded on the dorsum at its origin, a mesial carina gradually developing toward the aperture near which it becomes quite distinct, in some individuals, decidedly so. From this carina the sides slope evenly to the umbilicus, which they enter with a sudden curve, forming a low, indistinct, lateral carina, by the increase of curvature. Umbilicus apparently closed, the last volution alone being visible in the specimens examined. Surface of the cast smooth, traces of the original shell, however, seem to remain in a few spots, indicating a system of striæ curving from the mesial carina obliquely backwards, these apparently crossed by other striations. The usual form of the cast, however, is smooth, the shell being entirely removed.

Measurements, on account of the imperfect preservation of the shell towards the aperture, are of little value, still the following will serve to give a general idea of the proportions of the shell. Greatest diameter of the typical specimen (Plate XIII, Figs. a, b.), 9 mm.; diameter at right angles to this, 6.2 mm.; diameter of last volution at the point where it becomes visible, 3.5 mm.; broadest part of volution preserved, 7 mm. From this they vary in size from specimens which become almost minute to some having a greatest diameter of 22 mm.

Locality and position. Beavertown marl, Huffman's Quarry, Clinton Group. (Name signifying *quite small.*)

GENUS BELLEROPHON, Montfort.

IX. BELLEROPHON FISCELLO-STRIATUS, *sp. n.*

(*Plate XIII, Figs.* 19 *a, b, c, d.*)

Shell sub-discoid; only the last volution known, increasing rapidly in size, being almost four times as large at the aperture as at the point where it first becomes visible; the increase in size is quite regular, except near the aperture where there is a moderate expansion of the volution; aperture not distinctly preserved, but apparently the aperture was dorsally sinuate, the sinuation being simple and broadly V-shaped: this, however, can not be conclusively determined. Umbilicus quite large, and deeply defined. Dorsally the curvature of the shell toward each side is even and moderate, laterally the curvature is very sudden, the curvature of the sides into the umbilicus equaling or even exceeding the dorsal curvature of the shell; by this means the umbilicus is deepened and the sides of the shell appear raised, almost carinated towards the aperture.

Surface marked by fine longitudinal striæ, of which thirteen may be counted on each side of the carina as far as the beginning of the umbilicus, these are increased by intercalations with the age of the shell. Transverse striæ in the direction of the lines of growth, the striæ on opposite sides of the carina having an angle to each other equal to that which the sides of the sinus of the aperture seem to have. A third, less distinct system of striæ, originating at the carina, seems to make about the same angle with the longitudinal striæ as the transverse striæ just described. As a result of all these striations, the surface of the shell is divided up into many minute, many-sided polygons which give the shell a beautiful appearance. This is enhanced by a low, distinct carina, slightly raised at the sides and thus becoming grooved. Along the carina only afew, indistinct, longitudinal striæ are here and there visible, there are however many fine transverse striæ, bending backward into the groove of the carina.

Greatest diameter (extending through the aperture), 11 mm.; diameter transverse to this, 9 mm. Diameter of the last volution at its beginning, 2.5 mm.; at the aperture, the diameter passing through the dorsum is 5 mm.; the one transverse to this, 9 mm. The width of the carina, .4 to .5 mm.

Locality and position. Stolz's Quarry, Clinton Group.

CRUSTACEA.

I.	Acidaspis ———,	
II.	Bathyurus, ———,	
III.	Illænus Daytonensis,	Hall and Whitfield.
IV.	— Madisonianus,	Whitfield.
V.	— ambiguus,	n. sp.
VI.	Calymene ———,	

VII.	Calymene Blumenbachii ?	Brongniart.
VIII.	Lichas breviceps,	Hall.
IX.	Arionellus ? ———,	
X.	Dalmanites Werthneri,	n. sp.

The trilobites so far studied seem to be either identical with, or closely related to Niagara forms. Hall and Whitfield, in their description of *Illænus Daytonensis*, say that "specimens having the same features have been collected from the Niagara Group of Wisconsin and Illinois." *I. Madisonianus* is found in Wisconsin; however, I am unwilling to consider this as good evidence, since the identification is based upon one specimen, and that, the pygidium. *I. ambiguus* finds a close relation in *I. insignis*, a typical, western Niagara fossil. *Lichas breviceps* agrees quite closely in all important characteristics, especially those of the pygidium, with described forms of this species from Waldron, Indiana. *Dalmanites Werthneri* is closely related to *D. vigilans* and *D. verrucosus*, also from the Niagara strata of Indiana. Of the other species not much can be said in the present state of knowledge concerning them.

GENUS ACIDASPIS, Murchison.

I. ACIDASPIS ———.

(*Plate XIII, Fig.* 23.)

A fragment of a trilobite belonging to this genus has been found, presenting chiefly the movable cheek, but also portions of the glabella.

Glabella poorly preserved; including the occipital regions its breadth, as nearly as can be determined, is equal to about one third or two fifths its length, the widest part being behind the middle, between the eyes; lateral lobes apparently three on each side, the middle and posterior lateral lobes along one side of the glabella being distinctly defined in the specimen, the third, anterior lobe, less plainly, on account of the imperfect preservation of the fossil at this point. Lateral lobes of an almost oval outline, directed obliquely forward and outward, the posterior one larger than the middle lobe, separated by a distinct furrow from the cheeks and from themselves; there is a broad groove between the lateral lobes and the glabella proper, in addition to which the furrow between the middle and posterior lateral lobes and the occipital furrow rounding behind the posterior lateral lobe bend towards one another between the posterior lateral lobe and the glabella, which they seem to connect by means of the raised portion left between them; this connection is not altogether destroyed by the low groove which separates them. The occipital regions curve strongly downwards towards each side, behind and below the posterior lateral lobe, then slightly outward and forward. On this account the posterior margin of the glabella is considerably deflected on either side, beginning a considerable distance beneath the surface of the lateral lobe and fixed cheek, thence rising to almost the level of the glabella and again descending on the other side, being gracefully undulated in this way. The occipital furrow extends from the lower part of the posterior lateral lobe, behind this lobe, as described above, reaching a little more than one third the distance across the glabella. The slope of the rear of the posterior lateral lobe to the occipital regions below is almost vertical.

Fixed cheek divided from the movable cheek by a furrow, which between the middle lateral lobe and the anterior lateral lobe approaches closely to the furrow dividing the lateral lobes from the cheek; thence the former is gradually separated from the latter until it meets the inner margin of the eye, behind which it seems to curve and then become indistinct. Anteriorly the fixed cheek slopes rapidly downward and forward, posteriorly it curves far more rapidly downwards, incurving a little below, so that a distinct furrow seems to separate it from the occipital regions of the glabella; another furrow, starting at the junction of the glabella and fixed cheek, curves around behind the eye, separating the raised portion of the cheek between the eye and the glabella, from the posterior margin of the cheek.

Eye not preserved, judging from indications they were small, placed in a line with the rear of the posterior lateral lobes.

Movable cheek grooved near the fixed cheek, the groove following the direction of the furrow separating the cheeks; that part of the movable cheek between the groove and the furrow following the curvature of the fixed cheek. From this groove there is a gradual downward and outward curvature of the cheek, the same being true of the portions at the side of the eye. Behind the eye, there is a more sudden downward and backward curvature, the groove above mentioned extending behind the raised regions about the eye near the posterior margin of the cheeks, spreading out and becoming indistinct towards the lateral margin of the head. The posterior and lateral margins of the cheek are distinctly raised so as to form a ridge around the cheek. From the junction of the lateral and posterior ridge a long, sharp spine extends almost directly backward, and a little downward. Along the lateral ridge of tbe cheek are arranged a number of short spines about one third as long as the postero-lateral spine. The lateral spines curve obliquely backwards. They are apparently almost equidistant from each other and decrease in length anteriorly. There is a lateral spine at the origin of the postero-lateral spine, from this point to a point opposite to the groove between the middle and anterior dorsal furrow 10 spines may more or less distinctly be discerned.

The general curvature of the head is semi-circular from side to side, the convexity from the anterior portion to the posterior of the head being far less, although the exact amount can not be determined on account of the imperfect preservation of the middle and anterior portions of the glabella.

Surface, wherever preserved, distinctly pustulose.

Probable length of glabella, 14 mm.; breadth of the same, 19 mm.; height of the middle part of the occipital margin above its lateral extremities, 5 mm.; length of the lateral spines, 2.5 mm.; length of the postero-lateral spine, 7 mm. Height of the preserved part of the glabella above the margins of the head, 10–11 mm. Probable width of the entire head, 25 mm.

Locality and position. John Brown's Quarry, New Carlisle, Ohio, from the collection of the Ohio State University, kindly loaned by Prof. Edward Orton.

GENUS BATHYURUS, Billings.

II. BATHYURUS ———.

(*Plate XIV, Fig.* 5.)

Only a single fragment known, whose relation to this genus is rather conjectural.

Glabella conical, convex, distinctly defined anteriorly and laterally by a continuous quite deep furrow. Posteriorly a small oval, almost triangular tubercle is inserted between the occipital furrow and both of the postero-lateral extremities of the glabella; owing to these tubercles the outline of this portion of the head (the regions of the glabella) seems to broaden at their insertion and then to contract suddenly behind them, meeting the occipital furrow at a considerable angle, within a line directly behind the postero-lateral extremities of the glabella proper. Dorsal furrow well defined, running behind the tubercles, forward to a point almost even with the anterior margin of the tubercle, then back again on the other side. Posterior margin of the regions of the glabella an almost straight line running just behind the posterior ends of the tubercles. Glabella proper indistinctly marked by faint grooves. One of these grooves cuts off from the postero-lateral extremities of the glabella, parts somewhat larger than the tubercles. A second groove (also directed obliquely forward, but at a smaller angle) is placed a little anterior to the middle of the glabella, and extends about one third of the distance across the glabella. Anterior to this are one or two additional grooves, more faint, and also directed obliquely forwards, at a slightly greater angle than the last. All of these grooves are visible only after careful examination.

The anterior margin of the head curves quite rapidly downwards, so that the general shape of the preserved parts of the head is even more convex anteriorly than laterally or posteriorly. Anterior margin separated from the rim by a sort of furrow, from which the narrow rim rises up at an angle of about 45 degrees. The rim lies in a broad curve, passing within a short distance of the groove defining the anterior portion of the glabella. The facial sutures begin at the rim on a line about even with the lateral margins of the tubercles, thence extending inwards with a slow curvature, approaching within a very short distance of glabella behind its middle, and then apparently extending outwards where the outline is lost from want of preservation of the fossil. The antero-lateral extremities of the margin are therefore almost rectangularly pointed.

Length of the glabella to the occipital furrow, 7 mm.; to the posterior margin, 8.2 mm.; from the posterior margin to the anterior rim, 10 mm. Breadth of the glabella at its middle, 6.2 mm.; at its posterior, 6.9 mm.; across the tubercles, 7.4 mm. Distance between the tubercles, 4 mm. Length of the anterior rim, about 7.8 mm.

Locality and position. Soldiers' Home Quarry, Clinton Group.

GENUS ILLÆNUS, Dalman.

III. ILLÆNUS DAYTONENSIS, *Hall and Whitfield.*

(*Plate XIV, Figs.* 4 *a, b; Fig.* 6; *Figs.* 7 *a, b, c.*)

Species described by Hall and Whitfield in Ohio Pal. Vol. II.

Fixed cheeks one-third as wide as the space between the dorsal furrows. Palpebral lobes not coming to as sharp a point as figured in the Ohio report, but apparently a little rounded at their ends. Postero-lateral limb of the glabella beginning with a small groove at the base of the dorsal furrow which gradually widens towards the suture line, where it extends from the palpebral lobe to the occipital margin. Posterior portion of the facial suture curves outward from the posterior of the palpebral lobe, cutting the occipital margin at, or slightly beyond a line vertical to it and drawn from the most prominent part of the palpebral lobe.

Anterior margin of the pygidium trilobate, the middle lobe projecting a little, the lateral ones slightly curved at first, almost straight, then bending strongly and obliquely backwards, more or less angular at this point; then curving around and after a slightly angular deflection coalescing with the lateral margin. Antero-lateral angles never so prominent as those figured in the Ohio Report, although somewhat approaching them in this feature.

Movable cheeks small, greatest elevation at the upper posterior margin, making a large sweeping curve as it passes from the posterior to the lower or lateral margin. The facial suture before the eye making an angle of 30 degrees with the lateral line. Since this suture line agrees with the corresponding part of the glabella, these separated cheeks have been referred here.

Glabellae, pygidia, and movable cheeks so far not found in connection. The association of the glabellae and pygidia may be considered certain from their relative frequency and similarity to nearly related species. The cheeks are more conjectural in their relationship, although tolerably certain from their form.

Smallest glabella, 9x11 mm. One of larger size, 40 mm broad at the palpebral lobes, 30 mm. long, 13 mm. high. Smallest pygidium, 4x5 mm. One of larger size, 34 mm. broad, 25 mm. long, 5 mm. high. Movable cheeks 7-8 mm. broad, 12 mm. long to the point where it disappears beneath the glabella. Eyes two mm. long in the small specimens found.

Locality and position. Soldiers' Home, Fair Haven, Preble county, Clinton Group, abundant.

IV. ILLÆNUS MADISONIANUS, *Whitfield.*

(*Plate XIV, Figs.* 1 *a, b; Figs.* 2 *a, b.*)

Pygidium paraboloid in outline, its anterior margin arching strongly forward in the middle, and its surface very convex. Lateral margin spreading, forming a broad shallow furrow around the sides and behind, just within the edge; anteriorly this furrow extends up the articulating slope or facett of the pygidium, leaving it at about half the distance from the top of the anterior margin. Anterior margin with a rounded ungrooved edge, its corners just without the lateral furrows deflected downwards and forwards. A narrow faint ridge running from the posterior edge, half way up the pygidium. Entire surface minutely punctate with small pits .1 mm. in diameter, these interspersed with others of still smaller size.

Length, 30 mm.; breadth, 38 mm.; height 14 mm.; extension of the anterior margin forward beyond a line connecting the antero-lateral extremities, 9 mm. At the middle of this line is found the greatest elevation of the pygidium.

Our specimen is less abrupt at the sides than the one figured by Whitfield and has a smaller elevation along its posterior portion, but the general characters agree very closely with the published description and figures of the original. The recurved spreading margin seems to distinguish it from *I. insignis* of Hall, the nearest related species.

Locality and position. Clinton Group, Huffman's Quarry.

Another individual from the Soldiers' Home Quarries is proportionately broader, more depressed, less extended anteriorly, and provided at the anterior margin with a groove. Otherwise it agrees closely with the above form.

V. ILLÆNUS AMBIGUUS, *sp. n.*

(*Plate XIV, Figs.* 9 *a, b; Figs.* 10 *a, b, c; Fig.* 11.)

Glabella regularly arcuate from front to base; anterior border with the margin neatly rounded. Occipital furrow well defined, with a faint upward extension at its middle, barely visible, within which is a minute granule, which can readily be recognized on wetting the specimens. Extending towards the anterior margin from this part is an indistinct ridge, which can be recognized only with difficulty, except in an occasional specimen where it may become moderately distinct.

This corresponds to a much more evident (although narrow) ridge, on the pygidium associated with these glabellae. In the occipital furrow at about two-thirds the distance of its postero-lateral margin from the granule is a deep, very distinct pit becoming shallow in older specimens.

From this the dorsal furrow extends inwards as a deep groove forming a broad, oval depression opposite the palpebral lobe, thence it extends as a shallow groove, rapidly becoming indistinct, in an outward direction, terminating in a small pit, which can be easily recognized even in specimens which do not show the connecting part of the groove distinctly, as is usually the case. This pit contains a minute granule. It is situated at two-thirds the distance of the anterior margin from the palpebral lobe. Half way between this pit and the anterior margin is a minute granule, easily visible on wetting the specimen. Widest part of the glabella lies between the palpebral lobes, anterior to which it becomes narrower and again widens reaching almost the same width at a point just behind the junction of the facial suture with the anterior margin. Facial suture extending from the edge with a distinct outward curvature to a point opposite the terminal pit of the dorsal furrow where it makes a rapid curve inwards to its junction with the anterior margin, in which the facial suture seems to terminate without any break. Palpebral lobe rounded. Facial suture behind the palpebral lobe starts from the posterior incurved extremity of each eye, and curves rapidly outward, cutting the margin directly behind or a slight distance beyond a vertical line drawn from the most prominent part of the palpebral lobe to the occipital line. Greatest elevation of the glabella lies between the palpebral lobes.

Pygidium semi-circular in outline, becoming slightly paraboloid in larger specimens, with a narrow more or less strongly marked ridge. Ridge extending from the posterior margin upwards, usually not reaching the middle of the pygidium. It can always be recognized. Along the anterior margin lies a groove, which is somewhat straight along its middle third, a small inward curvature near the middle, being very slight, aids in this appearance. At either side the groove makes a short curve inwards, and then outwards, approaching the lateral margin, along which it extends for a short distance, rapidly becoming obsolete. The deflection of the antero-lateral border causes a raised, ridge-like eminence to remain between it and the antero-lateral portion of the marginal groove. Pygidium flattish along the upper anterior surface; greatest elevation at one-third the distance from the posterior margin, from this point rapidly curving downwards to the posterior margin, less rapidly towards the side and anterior portion.

Movable cheeks broadest at the posterior end of the eyes, with a deep-rounded furrow around the base of the eye. In large specimens rounded above. The facial suture inclining at an angle of sixty degrees to the lateral margin in front and meeting it at an angle behind which might be called a right angle, with the vertex rounded. It has also quite a sharp edge along its posterior margin, where the cheek makes a curve beneath the glabella. Since the angle made by the facial suture anterior to the eye corresponds to that made by the suture anterior to the palpebral lobe in the glabella, the cheeks are associated with this species. Eyes placed almost parallel with the upper part of the movable cheeks, lunate, forming about one-third of a circle. Lenses minute, about 17 to a millimeter. In the specimen examined they were only fairly preserved but there were about 20 in the vertical rows and perhaps 125 in the horizontal ones.

Glabellae, pygidia and movable cheeks so far not found in connection. The association of the glabellae and pygidia may be considered tolerably certain from the great abundance of both as compared with those of *I. Daytonensis*, the only other species found here in abundance. The association of the movable cheeks with these forms is more conjectural.

Smallest glabella, 8x10 mm. Ordinary sized specimen, 38 mm. broad across the palpebral lobes; 35 mm. across the anterior pits of the dorsal furrows. Direct length of glabella from anterior to occipital margins, 23 mm.; from anterior margin to a line drawn from the occipital margin perpendicular to the plane of the lateral margin, 20 mm.; height, 14 mm. A few large forms have been found which I refer to this species. The largest and most perfect of these is in the collection of Ira Crawford. It measures 60 mm. across the palpebral lobes and 54 mm. in a direct line from the anterior to the occipital margin; height, 30 mm. Smallest pygidium 10x13 mm. Ordinary sized specimen, 29 mm. broad at the antero-lateral margins; 24 mm. from posterior to articulating margin; 8 mm. high. A single large pygidium referred here measures 52 mm. in width; 44 mm. in length; 16 mm. in height. Movable cheeks, large specimen, length, 31 mm.; breadth, 20 mm.; length of eye, 7 mm. Smaller specimens proportionate.

Usually in the form of casts, surface where preserved apparently striated concentrically, at least around the edges, and dotted with small, shallow pits.

Locality and position. Soldiers' Home and vicinity. Clinton Group. Abundant.

GENUS CALYMENE, Brongniart.

VI. CALYMENE ———.

(*Plate XIII, Fig.* 24.)

Portions only of the head found, as fragments; the figure partly a restoration effected by a comparison of numerous fragmentary specimens. A fuller description will be given in the next paper if better material be found.

Glabella more prominent than the cheeks, very strongly defined from them by a deep, flat, longitudinal depression, which extends from the tip of the middle lateral lobe forward, forming an almost straight line along the line of separation from the fixed cheek, and terminating near the anterior end of the glabella, the side towards the fixed cheek being somewhat pointed. A similar depression behind the middle lateral lobes separates the posterior lobes from the surrounding portions of the head, its curvature being about that of the margins of the posterior lobes. The anterior border of the head is *broad* and *flat,* and directed upwards, with no arching along the middle as in specimens of *Calymene Niagarensis.* The anterior rim of this border has a slow curvature, appearing more like a straight line in some specimens than any species I am acquainted with. In other specimens, however, there is a somewhat greater curvature to the anterior rim. The facial sutures beginning with a slight outward curve for a small distance become almost parallel to each other as far as the eyes (which I now believe are incorrectly indicated in the drawing). Occipital furrow and as much of the fixed cheeks as is preserved, seem similar to the corresponding regions of *C. Niagarensis.*

Measurements are not given, on account of the unsatisfactory condition of the specimens. The figure is based upon a specimen preserving the glabella, anterior border and portions of the fixed cheeks, (all of the cheek anterior to the middle lateral lobe on one side of the glabella.) The rest of the figure is the result of comparison. The description is given mainly to note the existence of a form which has a *broad, flat, anterior border, with no arching in the middle, and with almost parallel facial sutures anterior to the eyes.* It will be made the object of future study.

Locality and position. Soldiers' Home Quarries, Clinton Group; not rare.

VII. Calymene Blumenbachii? Brongniart.

(*Plate XIII, Fig.* 25.)

General form broadly oblong.

Cephalic shield short and broad, the width twice as great as the length. Glabella quite prominent, projecting above the rest of the head; its general form, including the lateral lobes, conical, widest across the posterior lobes, the width at this point slightly more than its length excluding the occipital ring, and only four-fifths its length including the same. Glabella supplied with three more or less distinct lobes laterally, the posterior lobes large and prominent, equal in elevation to the glabella between them, although they seem to rise above it, on account of its downward slope posteriorly; the middle pair of lobes about half their size, the anterior pair small, indistinct. The middle and posterior pairs of lobes separated from themselves by deep grooves, from the glabella by grooves becoming shallow at the point of union of the lobes with the glabella, and from the cheeks by grooves of less depth, becoming shallow at the middle lobe; a slight groove anterior to the occipital furrow connects the deepened grooves extending along the anterior edge of the posterior lobes. The anterior part of the glabella quite regularly rounded. The curvature of the glabella towards each side much larger than along its length, the latter being almost regular along the middle of the glabella. Occipital furrow very distinct, arched forward along the centre, curving forward also at each side, around the posterior lobe; the posterior edge following about the direction of the occipital furrow. Anterior border of the head forming a broad and even curve about the head, the border *fairly broad, flat, turned a little upward, not arched in the middle*, somewhat like the species last described. Facial suture beginning with a slight outward curvature at its very origin, then a gradual inward curvature as far as the eye, then it curves around the eye, and posteriorly to it takes an almost lateral direction as far as the edge of the elevated regions of the head, along this edge it is directed to the postero-lateral edge of the head. Palpebral lobe fairly prominent. Fixed cheeks provided with a very deep and broad furrow close to the posterior margin, following its direction. Movable cheeks with thick, rounded lateral margins, defined by a distinct, rounded, lateral furrow, above which the remaining portion of the cheek is decidedly elevated. The curvature of the anterior and lateral margins of the head is quite regular, with the exception of a slight more or less evident inward curvature just behind the origin of the facial suture.

Thorax not entirely preserved, the number of articulations not known. Central lobe of the articulations elevated above the lateral lobes, more arched than the lateral lobes, separated from them by a distinct longitudinal furrow. Segment of the middle lobe arched forward along the middle, also bent a little forward at the sides, where they show a low, nodal thickening. The grooves separating the segments deeper at the sides, leaving a sort of axis along the centre of the middle lobe. The articulations of the lateral lobes extend laterally for a short distance and then are deflected posteriorly to their ends. A longitudinal furrow extends along each articulation dividing off its anterior part by a deeper and broader furrow than that which separates the articulations from each other.

Width of the head, about 64 mm.; length, 30 mm. Width of the glabella across the posterior lobes, 21 mm.; length, not including the neck segment, 19 mm.; including the same, 24 mm. Distance between the points of union of the facial sutures and the lateral margins, 19 mm.; forward extension of the anterior border, 6.5 mm. Probable length of the entire specimen, 105 mm.

Locality and position Allen's Quarry, Clinton Group, in the upper shaly course. The specimen crumbled partially away on removal.

Fragments of glabellae and surrounding portions belonging to this species are found at the Soldiers' Home Quarries, also near the top of the group, in the upper shaly courses. Associated with these are pygidia, which seem to belong to this species, the connection is, however, rather conjectural than otherwise.

Pygidium wider than long, the posterior edge making a very broad curve, almost straight along the middle. The anterior and lateral margins as far as preserved having an almost semi-circular outline. Middle lobe rapidly tapering posteriorly, segments about eight, the tip of the lobe (for an extent corresponding to about two segments) not divided, rounded posteriorly, the segments nearest the thorax similar to the segments there found. The more posterior segments have their ends curved decidedly backward, so as to follow the general semicircular arrangement of the articulations of the lateral lobes. Lateral lobes divided from the mesial lobe by a distinct, quite deep furrow, broadening posteriorly. Articulations about six. The anterior articulations together with the segments of the mesial lobe forming a semi-circular curve. The posterior articulations become less curved and take a more decidedly backward direction. The last pair of articulations in this way become almost parallel to one another and together with the posterior edge of the pygidium form a sort of box into which the unsegmented portion of the mesial lobe enters from above. The articulations of the lateral lobes are furrowed above along the middle, the furrows extending almost to the edge of the pygidium.

Surface of the pygidia, and the head and thorax described above, finely granulated.

Width of pygidium, 37 mm.; length, 25 mm.; width of the anterior end of the mesial lobe, 15 mm.; width at the beginning of the unsegmented posterior portion, 6 mm.

Locality and position. Allen's and Soldiers' Home Quarries, in the upper, shaly courses of the Clinton Group.

GENUS LICHAS, Dalman.

VIII. LICHAS BREVICEPS, *Hall.*

(*Plate XIII, Figs.* 26 *a*, *b*, *c*, *d.*)

Glabella (Fig. 26 b) of one specimen convex. The middle lobe rounded in front, on each side suddenly and deeply incurved by the introduction of two lateral lobes, the sides almost parallel for a short distance posteriorly, then curving for a short distance outwards so as to meet the occipital furrow; at the point where the last curvature begins the posterior part of the lobe is 2.5 mm. broad, along the occipital furrow, 5 mm.; the width of the lobe is exactly equal to its length. Lateral lobes sub-reniform, almost twice as long as wide, separated from the middle lobe by sharp grooves evenly curved except at the posterior end where the expansion of the posterior end of the middle lobe causes a slight irregularity of curvature; anteriorly the lateral edges of the lateral lobes continue the curvature of the anterior edge of the middle lobe, then they make a slow broad inward curvature, the posterior edge of the lobes being bounded by a groove continuing that part of the occipital furrow extending beneath the middle lobe. Within the inward curve of each reniform lateral lobe lies another lobe which I shall here call the *postero-lateral* lobe. Postero-lateral lobe separated from the lateral lobe by a sharp groove, its posterior edge is defined by a continuation of the groove behind the lateral lobes, directed a little backwards, however; from the palpebral lobe it is separated by a distinct groove curved outward and then inward, the curve disposed to be angular at its middle. Palpebral lobe preserved only anteriorly, its outer lateral edge elevated above the inner, the whole palpebral lobe having evidently been elevated along its outer surface. Postero-lateral tubercles transversely oblong lanceolate, inserted beneath the lateral and postero-lateral lobes, posteriorly they are bounded by the occipital furrow which bends somewhat backwards from the postero-lateral edges of the middle lobe so as to define the edges of the tubercles. The posterior edge of the neck segment has a very slight forward curvature towards the middle. Anterior margin of the head narrow. Surface irregularly pustulose.

Width across the widest part of the middle lobes, 8.6 mm.; across the lateral lobes, 9.5 mm.; across the postero-lateral lobes, 11.5 mm.; across the postero-lateral tubercles, 8 mm. Distance between the tubercles, 4 mm. Length of the middle lobe, 8.6; including the neck segment, 10 mm. Stolz's quarry.

Another glabella shows only middle, lateral, postero-lateral and palpebral lobes, with only a little of the neck segment nearest to the occipital lobe. It agrees with the foregoing specimen in all particulars as far as can be seen, except in the existence of a low groove across the posterior end of the middle lobe where it begins to take an outward curvature. This groove is parallel with the occipital furrow just behind it. The palpebral lobe is also better preserved and shows a regularly rounded outer edge, the surface elevated along the outer margin. Surface of the glabella irregularly pustulose. John Brown's Quarry,, New Carlisle. Specimen almost twice the size of the last.

A third specimen (Fig. 26 a) differs widely from the two above in some things. It is far more convex, and proportionately wider. The grooves about the glabella and the lobes into which it is divided also differ materially, more so than the figure intimates, but a fuller description will be deferred until more and better material is at hand for accurate description. Stolz's Quarry.

Pygidium, general form semi-elliptical, quite straight along the anterior border, rapidly curved at its antero-lateral extremities. Axial lobe broad and strong, very prominent in the anterior part, rapidly narrowing and becoming low in the middle, and again widening posteriorly, but not equaling its anterior width; its width at the anterior margin one third the width of the pygidium; one distinct anterior annulation, with apparently a faint indication of a second. Lateral lobe with three segments on each side, and each marked by a distinct, longitudinal furrow along its middle. At their posterior side the two anterior lobes project a little beyond the margin of the pygidium, the rest of the outline being regularly rounded. The two anterior segments directed backwards, the posterior segment bent first a little outward then backward, filling up the outline along the contracted middle of the axial lobe. Under the exterior crust of the pygidium are a series of lamellose striations following the posterior and lateral outline of the pygidium and reaching about one-third the length of the pygidium towards the centre. Surface pustulose as in the first described glabella; having been found in the same piece of rock, it is supposed to be the pygidium of this species.

Length of the pygidium, 17 mm.; width, 24 mm. Width of the axial lobe anteriorly, 8 mm.; along the contracted portion, 4 mm.; at its greatest expansion posteriorly, about 6.5 mm. Stolz's Quarry. Other pygidia presenting the same features found here.

Locality and position. Stolz's Quarry, both glabellae and pygidia; John Brown's Quarry, New Carlisle, a glábella, kindly loaned from the collection of the Ohio State University, by Prof. Edward Orton. Clinton Group.

GENUS ARIONELLUS, Barrande.

IX. ARIONELLUS ————.

(*Plate XIV, Fig.* 3.)

It would be difficult to tell why the species here described should be placed under the generic name above mentioned, differing, as it does, in almost every important characteristic; nevertheless in some respects it seemed to me to be as closely related to this genus as to any other, and until further study may lead me to a more definite result, I concluded to leave it here.

Glabella very convex towards the anterior margin, which is rounded; less convex laterally; separated from the cheeks by almost straight furrows, converging behind to about four sevenths the width of the glabella at its broadest part. At about half the length of the glabella, on each side, are two grooves. The middle pair are broadly crescent shaped, the points directed downward, distant from one another about two fifths the width of the glabella at that point, their general direction being lateral; they do not quite reach the lateral margins, however. From the ends of these, a second pair of crescent shaped grooves extend forward and laterally, reaching the furrows which define the lateral sides of the glabella. The second pair does not merge into the first at their adjacent extremities. Behind these grooves a third pair, distant from each other about two fifths the width of the glabella at that point, cut off about one third of the lower half of the glabella; they are directed obliquely backwards, at an angle of about sixty degrees with a line extending lengthwise along the glabella; their curvature is first a little backwards, then more laterally, then a little backwards again, making a gracefully undulated curve which does not quite reach the lateral margin of the glabella; a fourth pair of grooves, cutting off the last third of the lower half of the glabella, is similar to this pair. The occipital furrow is scarcely preserved but seems to have been regularly curved, the middle of the curve being directed forward.

Fixed cheeks, at least as far as preserved, highest anteriorly, where their convexity is also the greatest. The front margin beginning just behind the first pair of grooves on the glabella is curved postero-laterally, then backward and slightly inward, lastly, again postero-laterally to the postero-lateral corner of the cheek. The occipital furrow extends laterally along the posterior border of the cheek near the margin as a deep furrow. Surface smooth.

Length of the glabella, 4.1 mm.; width at the broadest part, 4.1 mm.; at the narrowed posterior extremity, 2.4 mm.; width of that part of the head included between the postero-lateral corners of the fixed cheeks, 5.4 mm.; length of the fixed cheeks, 2.2 mm.

Locality and position. Soldiers' Home Quarry, Clinton Group.

GENUS DALMANITES, Emmrich.

X. DALMANITES WERTHNERI, *sp. n.*

General form of the body elongate-ovate, greatest breadth across the posterior part of the cephalic shield.

Head convex, semi-circular, breadth about five-thirds as great as the length; border extended in front into a semi-circular process, which varies from forms in which it is scarcely evident, to those in which it equals about two-fifths of the breadth of the anterior border in its projection beyond the curve of the border itself, never as distinct as in *D. vigilans*; base about one-fourth as broad as the greatest width of the glabella, or even less; lateral borders broad, separated from the cheeks by a distinct groove, produced posteriorly into rather long and slender curving spines, which continue the curvature of the lateral borders of the glabella.

Glabella large, depressed convex, widening in front to almost twice its width at the posterior margin, divided into lobes by three pairs of transverse furrows in addition to the occipital furrow, which is distinct and continuous. All three furrows distinct at the sides, not extending entirely across the glabella except in some specimens as a faint depression. Anterior furrows deeper, situated a little anterior to the eyes, giving to the frontal lobe a transversely elliptical outline; occipital ring narrow, without a spine as far as known. Eyes very prominent, short reniform, containing obout thirty-five vertical ranges of lenses, the middle ranges having six to seven each; palpebral lobe depressed, giving great prominence to the rim of the eyes. Cheeks small, anteriorly quite prominent, posteriorly marked by a deep, bordering groove, the continuation of the occipital furrow, margin flat.

Thorax with the axial lobe convex, widest at the sixth segment, its greatest width about two-thirds that of the lateral lobe, or a little larger. The articulations curve forward a little near the middle and at their junction with the lateral lobes; articulations of the lateral lobes traversed by a deep longitudinal furrow extending from the junction of the anterior margin with the axil lobe, backwards along the anterior margin of the articulation, at about one third the width of the articulation, leaving it towards the extremities. From the imperfect preservation, the exact method of leaving can not be determined.

Pygidium broadly ovate-triangular, the lateral borders flattened, axial lobe regularly tapering posteriorly, marked by about thirteen annulations, which gradually decrease in size posteriorly and end in a spinose elevation. This spinose elevation is often accompanied by an upward deflection of the border posteriorly and terminates in a minute point at the end of the border. Although the pygidia are very abundant no spinose projection beyond the border has so far been observed. Antero-lateral margin of pygidium rounded, lateral articulations about ten in number, all, except the last three, grooved like the articulations of the thorax, becoming indistinct on the margin of the pygidium.

Head irregularly pustulate (pustules small) except the anterior and lateral borders of the head, which are minutely granular. Remainder of the body irregularly pustulate, pustules small, a single pustule slightly larger in size on each segment of the axial lobe of the pygidium, inconspicuous.

Small specimen, length of body, about 25 mm.; breadth, 16 mm.; length of head, 9 mm., breadth, 15 mm. Head (of usual proportions), length, 12 mm.; breadth, 20 mm.; convexity, 4 mm.; breadth of anterior lobe of the glabella, 10 mm.; of the posterior lobe, 5½ mm. Pygidium, length, 17 mm.; breadth, 22 mm.; breadth of axial lobe anteriorly, 6 mm.

The furrows across the axial lobe are much more distinct at the sides than at the middle, especially in the pygidium. The anterior lobe of the glabella has near its posterior extremity a distinct, elongated pit, which seems to be characteristic of this species.

Locality and position. Soldiers' Home Quarries. Clinton Group. (Named in honor of Mr. W. B. Werthner, who was present at the first discovery of this species. Abundant in some localities.)

In connection with the minute forms described above from the Beavertown marl, the following will be of interest:

GENUS ORTHOCERAS, Breynius.

ORTHOCERAS INCEPTUM, *sp. n.*

(*Plate XIII, Figs.* 1 *a, b, c.*)

Shell very small and slender, enlarging from below upwards gradually, in one specimen from 4 to 5 mm. in a length of 10 mm., in others more slowly. Transverse section almost circular, one diameter slightly longer, or more elliptical; length of the outer chamber not determined. Septa concave—six chambers occupying a length of 10 mm. in the specimen above mentioned. Siphuncle eccentric, nearer to the centre than to the margin, narrow at the septa, expanding within the chambers.

Surface apparently not preserved, specimens in the form of casts. There are indications of longitudinal striæ, preserved with various degrees of distinctness, in some worn specimens looking like rows of small pits. Along one side of the shell, nearest the position of the siphuncle is a narrow, raised, longitudinal line, laterally defined by grooves which more or less coalesce anteriorly towards the annular rings (septa), and thus produce interruptions along the line. The distinctness of this longitudinal line is extremely variable, or perhaps is due to the removal of some of the surface matter, because some of the best preserved specimens are smooth, whereas those which are worn are apt to present these features. (Cf. *O. Duseri, Hall and Whitfield.*)

Locality and position. Beavertown marl, Clinton Group. A specimen in the Ohio State collection, from Wilmington, Ohio, I refer to this species.

EXPLANATION OF PLATES.

Plate XIII.

Fig. 1. *Orthoceras inceptum, n. sp.*: a, lateral views; b, views showing the position of the siphuncle; c, vertical section through the siphuncle.

Fig. 2. *Meristella umbonata, Billings* (sp); a, lateral view; b. dorsal valve.

Fig. 3. *Platyostoma Niagarense. Hall;* a, b, specimens referred to the Ohio forms considered identical with the Indiana species. having the aspect of *Holopea.*

Fig. 4. *Eichwaldia reticulata, Hall:* a, dorsal valve; b, ventral valve.

Fig. 5. *Leptæna prolongata, n sp.:* a. ventral valve; b, lateral view, outline.

Fig. 6. *Zygospira modesta, Say* (sp); dorsal valve.

Fig. 7. *Orthis biforata,* var. *lynx* (*Von Buch*), forma *reversata;* ventral valve.

Fig. 8. *Orthis biforata,* var. *lynx* (*Von Buch*), forma *Daytonensis;* ventral valve.

Fig. 9. *Atrypa nodostriata, Hall:* ventral valve.

Fig. 10. *Orthis hybrida, Sowerby:* a, dorsal valve; b, lateral view, drawn for the outline only.

Fig. 11. *Orthis elegantula, Dalman:* a, dorsal view; b, lateral view, drawn for the outline only.

Fig. 12. *Orthis flabella, Sowerby:* a, ventral valve; b, dorsal valve.

Fig. 13. *Orthis Daytonensis, n. sp.:* a, dorsal valve; b, lateral view, drawn for outline only ; c, a few of the radiating striæ; d, occasional appearance of the surface characters.

Fig. 14. *Pterinea brisa, Hall;* a, b, views of different left valves referred to this species ; b, taken from a cast.

Fig. 15. *Orthis fausta, n. sp ;* a, dorsal valve ; b, ventral valve ; c, lateral view ; d, a few of the striæ.

Fig. 16. *Orthis fausta, n. sp.;* a, dorsal valve ; b, some of the striæ of the form *acuto-plicata.*

Fig. 17. *Orthis elegantula, var. parva, n var.:* a, ventral valve; b, lateral view of the same.

Fig. 18. *Bucania exigua, n. sp.;* a, view from above ; b, lateral view, the expansion of the aperture not well brought out ; c, lateral view of another specimen ; d, another view of the same.

Fig. 19. *Bellerophon fiscello-striatus, n. sp ;* a, lateral view ; b, c, d, views of the same ; e, a part of the carina, with a few of the nearest striæ.

Fig. 20. *Orthis Daytonensis, n. sp.;* a, ventral view; b, interior view of the same.

Fig 21. *Orthis Daytonensis, n. sp ;* lateral view of a specimen presenting both valves.

Fig. 22. *Platyostoma Niagarense, Hall:* a, lateral view ; b, view from above.

Fig. 23. *Acidaspis;* part of the head.

Fig. 24. *Calymene;* part of the head, partially restored.

Fig. 25. *Calymene Blumenbachii? Brongniart:* head with a few of the thoracic articulations attached.

Fig. 26. *Lichas breviceps, Hall;* a, glabella, not typical ; b, typical glabella of Ohio form ; c, surface of the latter, variously magnified ; d, pygidium ; e, glabella of a specimen from New Carlisle.

Plate XIV.

Fig. 1. *Illænus Madisonianus, Whitfield;* a, view of a pygidium from above; b, lateral view of the same.

Fig. 2. *Illænus;* a, view of pygidium similar in some respects to that of *I. Madisonianus :* b, lateral view of the same.

Fig. 3. *Arionellus?;* view of the glabella and fixed cheeks.

Fig. 4. *Illænus Daytonensis, Hall and Whitfield;* a, view of a pygidium ; b, lateral view of the same.

Fig. 5. *Bathyurus;* view of a glabella, the curvature of the rim of the anterior border not represented.

Fig. 6. *Illænus Daytonensis, H. and W.;* movable cheek, view obliquely from below.

Fig. 7. *Illænus Daytonensis, H. and W.;* a, lateral view of a head, the associated movable cheek figured ; b, view of the glabella from above ; c, view of the same from behind.

Fig. 8. *Nucula minima, n. sp.;* a, view of the anterior regions ; b, lateral view; c, view of the regions posterior to the beaks; all views magnified six diameters.

Fig. 9. *Illænus ambiguus, n. sp.;* a, view of a pygidium seen from above; b, lateral view of the same.

Fig. 10. *Illænus ambiguus, n. sp :* a, lateral view of a head, the associated movable cheek figured; b, posterior view of the glabella; c, view of the same from above.

Fig. 11. *Illænus ambiguus, n. sp.;* movable cheek of unusually large proportions.

Fig. 12. *Grammysia Caswelli, n. sp.;* a, lateral view of the shell, anterior definition too sharp; b, view of the same from above.

Fig. 13. ——— *triplesianus, n. sp.;* a, view of one of the valves; b, lateral view of the same shell.

Fig. 14. ——— *triplesianus, n. sp.;* view of the other valve from a different specimen.

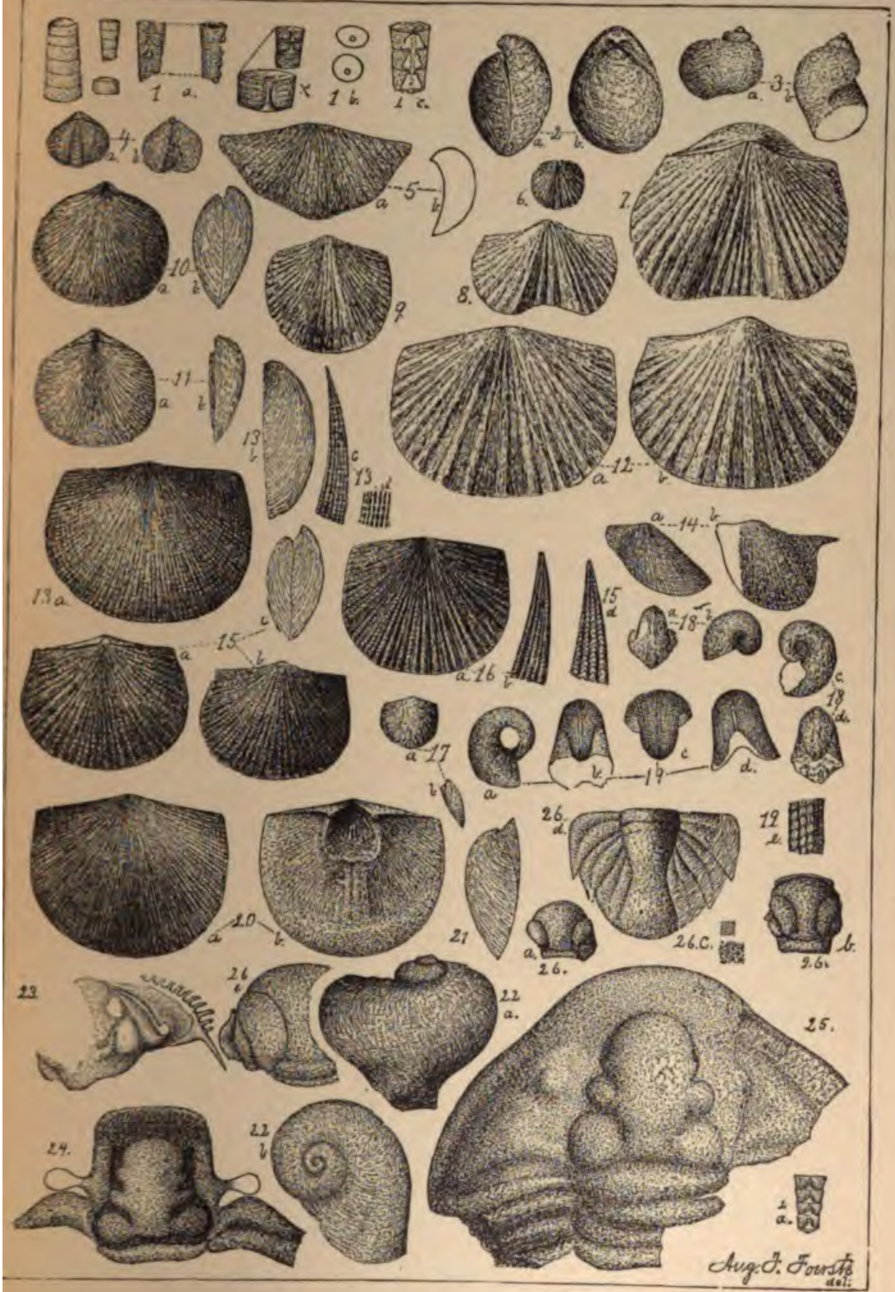
Fig. 15. *Strophostylus cyclostomus, Hall;* lateral view of a specimen.

Fig. 16. *Trochonema nana, n. sp.;* two views, magnified to eight-thirds and four-thirds of the original size respectively.

Fig. 17. *Cyclora alta, n. sp.;* a, lateral views of specimens showing variations in the elevation of the spire; b, view of the umbilicus of a specimen; all views magnified two diameters.

Fig. 18. *Raphistoma affinis, n. sp ;* view from above, and also a lateral view, the umbilicus being directed upwards.

PLATE XIII.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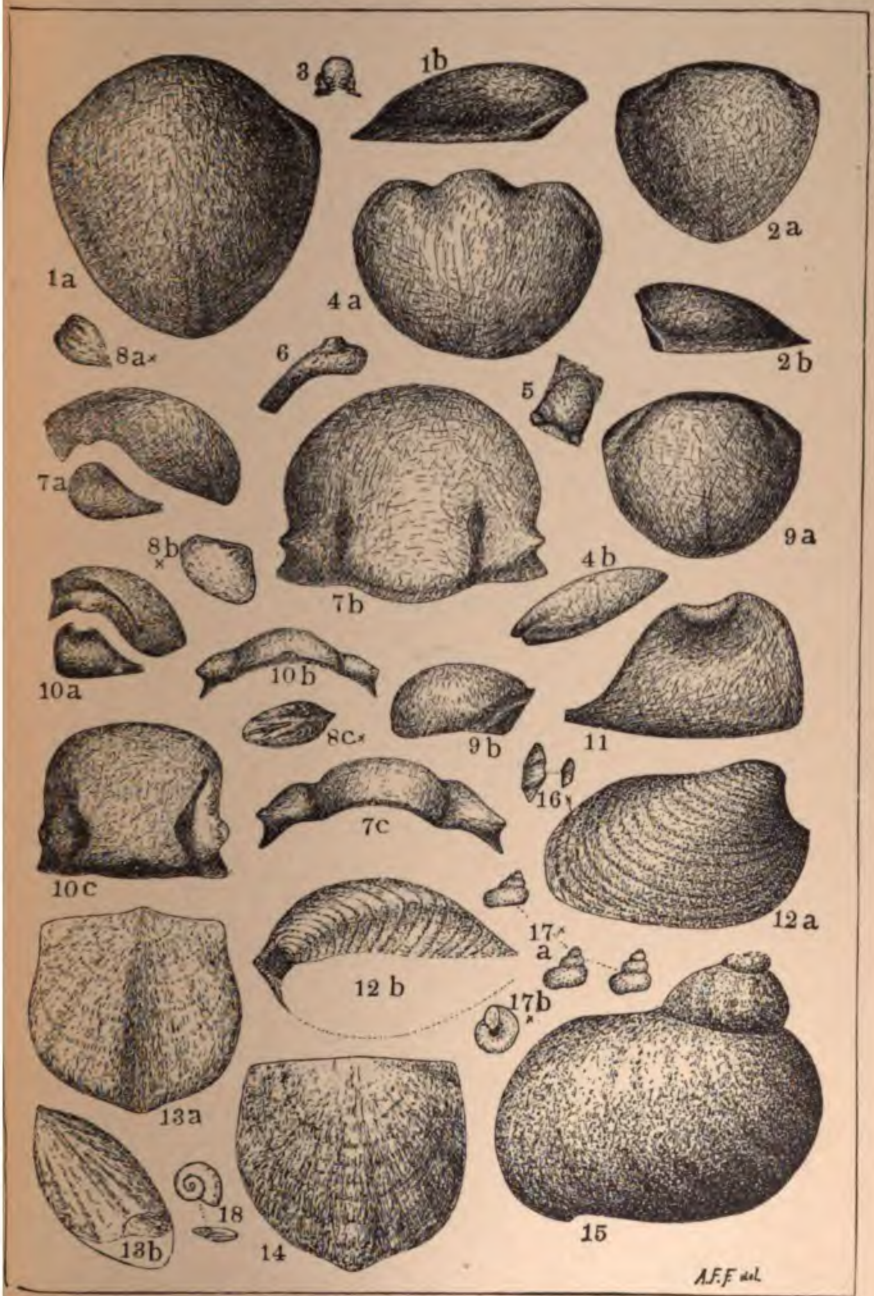
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VII.

A COMPEND OF LABORATORY MANIPULATION.

It is the design of the series of papers, of which this is the first, to present in concise form the methods of investigation which have proven themselves of greatest service in the laboratories of this country and Europe. No attempt at originality or completeness is made, but only such methods as have been experimentally proven useful will be admitted, while free use will be made of the modern text-books of Fol and Hussak.

It is acknowledged by all students that the proper method of research is the first essential to the prosecution of any line of investigation, and it is often stated that he who spends but half the time allotted to a given study in experimentally learning the best manipulation to employ, need not regret the time so spent.

The present paper deals with lithological appliances and methods and is supplemented by a condensed translation and adaptation of Hussak's "Einleitung." No apology is necessary for reducing the formulæ to the system in vogue in this country nor for giving prominence to the subject of lithology, in view of its rising importance and increasing recognition.

CHAPTER I.

LITHOLOGICAL MANIPULATION.

A. Rock Sections.

In no department of geology has there been so great an advance of late in this country as in the study of the intimate structure of rocks by means of thin sections. The science of lithology is rapidly evolving from a chaotic condition and assuming the similitude of a system. Although the pursuit of this study has been confined to a limited circle and it has scarcely appeared in our literature, much may be expected in the near future.

The impetus given years ago by *Zirkle*, in his "Microscopic Petrography," has slowly become apparent. Hawes, in his work upon New Hampshire lithology, contributed substantial material to the same science, while the more recent reports of the Wisconsin geological survey afford evidence that the work is going on. Several of the State geological surveys are now in the midst of investigations in this direction the results of which may be looked for with great interest. The United States surveys are not behind in cultivating the promising field.

Great as is the promise of research in this direction, we are equally interested to observe that the introduction of the new method of study of rocks is to a degree revolutionizing the study of geology. The same methods which have so greatly augmented the disciplinary value of biology by connecting histological and laboratory practice with its study, are introduced into the courses in geology and the student is taught to *see through*, as well as to look at, rocks and minerals.

The study of a rock or mineral involves, first, the investigation of the origin, age, and relations of the rock, which invoke respectively the sciences of geotechnical, historical, and stratigraphical geology; second, the study of the rock itself, which may be carried on by means of chemical and physical tests. Under the latter head come crystallography and physical mineralogy. The chemical examination involves the application of heat, as in blow-pipe analysis, or of chemical reagents in the wet way.

The physical examination of minerals may be conducted microscopically or macroscopically, depending upon the employment or non-employment of aids to ordinary vision. Ordinary physical mineralogy is occupied with such of the optical or other characters of minerals as can be made out with the unassisted eye.

In order to prepare a mineral or rock for microscopic examination it must, in most cases, be reduced to a transparent condition in order that it may be studied by transmitted light. The facts which can be obtained by the microscopic examination of opaque masses in reflected light, are few and unimportant.

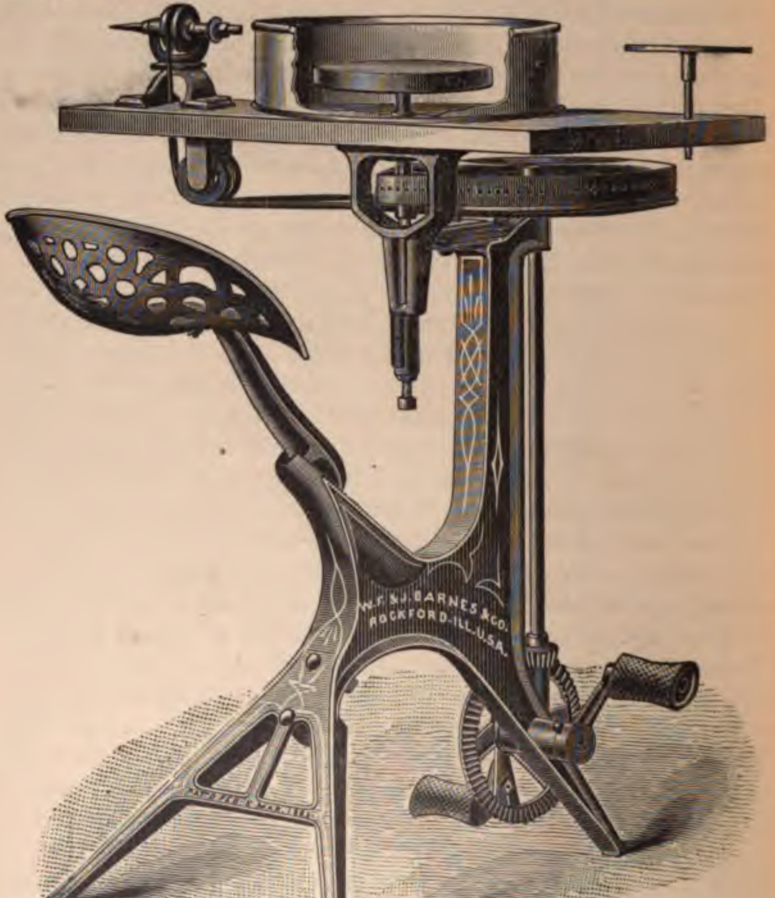
A rock may be reduced to a powder and mounted in a transparent medium and many of its elements detected by microscopic examination of the angles and surfaces of the fragments. In this way particles too small for measurement by the ordinary goniometer may be determined. Such of the resulting particles as are transparent may be optically examined, though there are many opportunities for error. It is recommended that rocks of a rather finely granular structure be examined in this way with reference also to the specific gravity. A fragment of suitable size is reduced to a powder, the fineness of which may vary with the size of the granular elements in the sample. The powder is then assorted under water by agitating repeatedly in a bottle and hastily pouring off the fluid, leaving the part first to settle and repeating the process as often as any separation is possible. Denser fluids (See Hussak Anleitung, p. 51,) may be used with advantage in some cases. By mounting different parts of the powder thus sorted separately or under separate covers upon a single glass slip, interesting qualitative and even approximate quantitative results may be obtained.

Comparatively few minerals or aggregates are sufficiently transparent to permit of optical examination by transmitted light. A few of these, as mica, gypsum, calcite, dolomite, etc., are adapted for study without other preparation in any way. In cases where the cleavage is irregular and does not permit the breaking out of tabular plates it becomes necessary to mount the irregular fragments in a highly refractive medium, such as balsam, between glass slips, and thus to eliminate as far as possible the dispersion and irregular refraction. Even then the results are often unsatisfactory. Sands and other fragmentary rocks may be examined by the following method, suggested by *Thoulet.*

The powder or sand is mixed with about ten times its volume of zinc oxide, then silicate of potassium is stirred in till the whole assumes the consistency of a stiff broth. This, while still soft, may be pressed into a mold, formed from a section of a glass tube glued to a slip. When set, the resulting cylinder is removed and fastened to a slip of thick glass and ground in the way described beyond for compact rocks.

When a rock or mineral is not transparent and does not admit of breaking into sections of suitable thinness with the hammer, it becomes necessary to cut or grind a section of sufficient transparency and then mount it between glass in Canada balsam. Before beginning this somewhat tedious process the student should provide himself with the following outfit: (1) A number of thick squares of plate glass about one half inch thick and two inches square, these being ground on the edges in order to avoid cutting the fingers; (2) several dozen slips of thin perfect glass for mounting the sections, the size preferred being 45 by 25 mm. and is furnished by any dealer in microscopes; (3) a corresponding number of covers of thin glass, square in shape and large enough to extend nearly across the slip; (4) a jar of balsam nearly solid or of the consistency of honey and lumps of solid balsam, (the balsam thould be in a wide-mouthed bottle covered with a protecting shield or glass stopper, through which extends a dipping rod); (5) several grades of emery powder, it being convenient to have numbers 0, and 1, and emery flour, as well as a small quantity of emery slime. This last is not kept by ordinary dealers and is made by decanting off the finest impalpable powder during the grinding of other grades. It may be secured of Julien, of New York, or through Bausch & Lomb, of Rochester; (6) an alcohol or gas lamp; (7) a heating table or tripod with brass plate, for heating the slides; (8) a number of spring clothes pins, with the lips filed flat, to hold the cover glasses while the balsam drys; (9) a bottle of solution for cleansing the glasses, which is prepared from sulphuric acid and chromate of potash; (10) a contrivance of some sort for grinding or sectioning the rock. The simplest way is, after breaking as thin a fragment as possible from an unweathered sample, to grind one side of the fragment upon a smooth iron surface with coarse emery and water until a plane surface is secured as large as a quarter or larger. The surface is then ground with emery flour upon a large, smooth plate of glass, after which a polish is secured by long rubbing on a second plate with emery slime. The surface thus prepared is glued to one of the squares of plate glass with balsam. The best results are secured by using balsam which is quite hard but not yet brittle; it should yield to the nail with difficulty, but should not shiver into fragments. A small piece is placed on the cleaned surface of the square and set on the brass plate of the tripod over the flame of the lamp. The chip of rock is also heated at the same time. When the balsam has become thoroughly fluid, but before bubbles appear, the section is pressed firmly down upon the balsam and as much of it pressed out as possible. Care should be taken that no bubbles or impurities find their way between the section and the glass. A weight or spring may, in some cases be necessary to prevent the slightest elevation of one side of the chip from the glass square. The balsam will set very quickly and, if the heating has been slow enough, will have become tough—it should no longer yield to the nail. The older lithologists advise the use of soft balsam, which is heated until it acquires the proper consistency before each mounting, in a spoon, but there are many objections besides the tedious process involved. When any number of slides are to be made there is economy in having balsam of the proper sort at hand and if some becomes brittle it may be melted with some which is yet too fluid. It is desirable also to perform the same part of the process with a number—say a dozen—samples at once, as it saves time and the chances of accident are fewer, provided care be taken to avoid loosing the identity of the specimens. After the chip has been glued to the glass square the former is ground carefully with coarse emory of various grades until the section shows signs of falling to pieces, it is then put upon the flour and slime plates in succession. Great care must be used to prevent the accidental mixture of coarse emery or gritty grains with the emery flour or slime, as one grain of coarse grit may suffice to destroy the section just when completed. When the section is judged thin enough, it is proved by cleaning the square and laying it over print which should be clearly seen through the section. The superfluous and soiled balsam is carefully cleaned away from the section and it is placed on the heating table on which are also laid the slip and cover glasses. When the balsam is fluid, a small fragment of somewhat more fluid balsam than that previously used is placed on the glass slip and the thin section is pushed off the plate glass square with a blunt needle, the cool needle adheres to the section and the latter is removed to the now perfectly fluid balsam on the glass slip. The warm cover glass is now quickly placed over the section which has been completely immersed in the medium. Care must be taken that a sufficient quantity of balsam is used to completely fill the space between the slip and the cover and also that no bubbles arise to obscure the field. If all has been successful the spring clips are applied and the slide is placed aside to dry without attempting to clean away the superfluous balsam. In a day or two this will be hard enough to be readily removed with a knife and the slide may be cleaned with a soft cloth wetted with alcohol, care being taken that the balsam under the cover is not attacked by the alcohol. The slide is then ready to label in any convenient way, the number of the corresponding hand sample being in every case attached to the slide.

The process above described is less tedious than might be supposed but can be materially shortened by the use of a lithological lathe provided with lead and iron horizontal laps. The accompanying wood cut illustrates the form of lathe used for this purpose in our own laboratory. It was manufactured at the suggestion of this department and is not only more convenient and elegant, but less expensive than any other lathe at present in the market. It is constructed by W. F. and John Barnes Co., of Rockford, Ill.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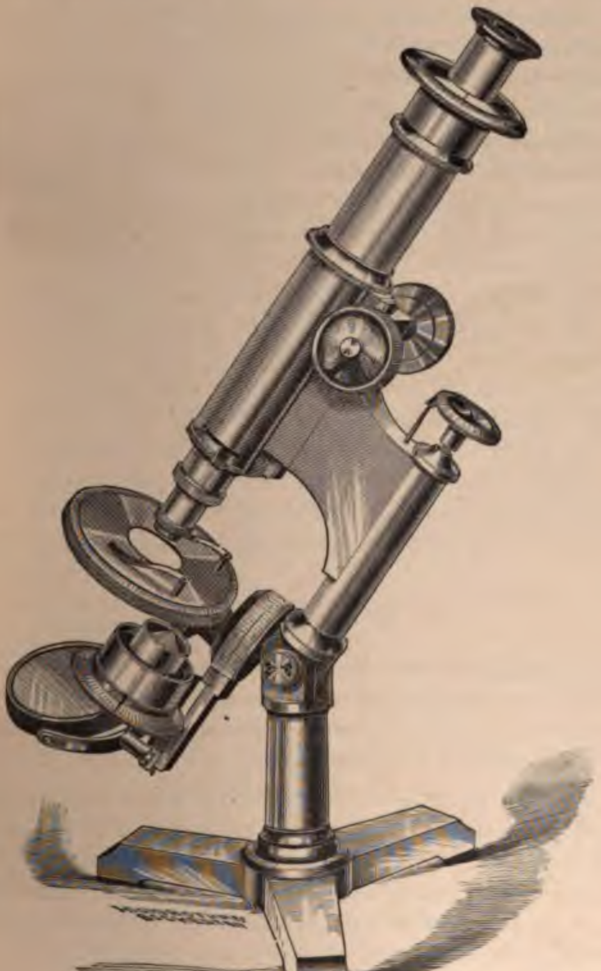
In the study of the section thus prepared a microscope is used which is especially arranged for this purpose. The appearance of such an instrument is illustrated by the accompanying figure which represents the polarizing microscope prepared by Bausch and Lomb, Rochester, N. Y., while figure 1. of plate XI gives a diagram of the optical parts, etc., of the Fuess-Rosenbusch stand in use in Germany.



The rotating stage is centered and graduated to record the angular position of the slide. The polarizer (rr) is placed below the stage and consists of a Nicols' prism set in a rotating cylinder. Above it is a condensing lense for making the rays convergent. The light is polarized in one plane by the polarizer and (the condenser being removed) passes through the section placed over the aperture in the stage. The resulting image is now magnified by the microscope in the usual way. Above the ocular is placed the analyser, consisting of a Nicol's prism set in a revolving cylinder with a graduated limb. This prism serves to cut off all the rays polarized in one plane by the lower Nicol when its axis is at right angles to that prism. If, however, the interposed mineral section is double refractive and rotates the plane of polarization of the light, this fact is indicated by the fact that the field does not appear dark when the Nicols are at right angles, but at some other angle which enables us to ascertain the amount of rotation produced by the mineral in question. A quartz plate (zz) is inserted above the objective and serves to discover the slightest double refraction. An artificial calcite twin, known as the Calderon plate, is inserted in one of the oculars. If the mineral examined be not isotropous the two parts will be unequally dark, thus enabling us to distinguish the optical characters by a most sensitive test. A plate of calcite, set in a cork ring, is also used between the ocular and analyzer. The interference figure produced by the calcite now is superposed upon the mineral section and may or may not be distorted by the action of the latter, affording another criterion by which to determine the minerals.

B. *Micro-chemical Methods.*

In the application of chemistry beneath the microscope, tests of prime importance are derived from the solubility of the various parts of a section and the forms of crystals formed from an evaporated precipitate after a reaction is accomplished.

In order that the tests may be applied to but a single crystal of a section, it is necessary to perforate the cover glass with a minute opening, thus preventing the uncertainty otherwise unavoidable. An ordinary cover glass is coated with wax and a minute perforation is made with a needle, exposing the glass, which is then subjected to the action of hydrofluoric acid until the glass is eaten through by a perforation less than a millimeter in diameter. The section is then covered and the opening is brought directly above the crystal to be studied. The balsam is removed by alcohol and the surface of the crystal is thus exposed to the action. In the case of reagents giving off corrosive fumes, the objective may be protected by a thin glass cover temporarily fastened to the end by glycerine.

As an example of the micro-chemical process we may mention the process of distinguishing apatite from nephelin. If the grain of apatite can be isolated it is dissolved in a concentric nitric acid solution of molybdate of ammonia. As the solution is slowly affected, a multitude of yellow octahedrons of $10 Mo O_3 + PO_4 (NH_4)_3$ appear about the edges. This detects the phosphoric acid. The lime may be demonstrated by dissolving the grain in nitric acid, to which is then added a drop of sulphuric acid producing small crystals of gypsum.

In case the questionable grain is in a section the acids may be applied with a glass rod and then removed by a pipette to a glass slip and there evaporated.

Nephelin fails to produce the reactions described but its solution in concentric hydrochloric acid affords, on evaporation, minute cubes of common salt which are very readily recognized.

Boricky has applied Fluo-silicic acid in the micro-chemical analysis of many minerals. The reagent must be chemically pure and about 13 per cent. strong. It cannot, of course, be preserved in glass vessels. Its availability arises from the fact that nearly all rock-forming minerals are attacked by it and the resulting compounds afford characteristic crystals.

A slide is covered with a thin protecting layer of balsam and upon this the particles to be examined are placed. When the substance is very slowly affected the best results are obtained by applying the reagent to the section itself. If the mineral is easily dissolved the various components appear approximately in their relative proportion in crystals of various form. In cases where the mineral is but slightly attacked, some of its components may first separate and thus make necessary a repetition of the process, or it may be faciliated by first dissolving these soluble substances in fluoric acid. The fluo-silicates crystallize most perfectly when evaporated and the watery solution permitted to again evaporate on a second slide.

1. *Fluo-silicate of postassium* crystallizes in the isometric system, usually in i–i in skeleton groups, also in 1, and I. The reaction is masked by presence of sodium, when apparently rhombic crystals ī–n . m–ī are formed.

2. *Fluo-silicates of sodium* give short hexagonal columns with O,

I, and i–2. Incomplete crystals are barrel-shaped, presence of calcium increases the size.

3. *Fluo-silicate of calcium* occurs in peculiar, long lanceolate crystals, often in rosettes. The angles and edges are not sharp. Monoclinic, easily soluble in water.

4. *Fluo-silicate of magnesium* appears in rhombohedrons the angles of which are truncated by oR, and in combinations of R . i–2 or R. i–2 . oR. It often appears in rhombohedrons deformed in one angle or in cruciate or pectinate forms.

Ferric and maganesic compounds can hardly be distinguished from magnesium fluo-silicate, and strontium compounds resemble fluo-silicate of calcium.

5. Lithia compounds appear in obtuse hexagonal pyramids, while fluo-silicate of barium occurs in excessively minute needles.

The fluorides of iron, magnesium, and maganese may be distinguished by subjecting them to the action of chlorine gas, which changes the color of the iron compound to citron yellow, of the manganese to reddish, while the fluoride of magnesia remains colorless.

Behrens gives the following method which, when carefully followed, is exceedingly delicate:—

The sample to be studied is isolated and pulverized and is placed in a covered platinum capsule not more than 1 cm. in diameter into which a few drops of fluoric acid, fluoride of ammonium, and concentrated hydrochloric acid have been placed, evaporate, and, if necessary, repeat the operation. The dried mass resulting is evaporated with sulphuric acid nearly to dryness, when gray fumes are formed. Add water and again evaporate so that for each milligram of the powder a centigram of fluid is produced. A drop of this fluid is now placed on the slide with a capillary pipette and, after protecting the objective, is examined for *calcium*. If calcium is presant, evaporation produces crystals of gypsum (I . i–i' . 1 .) On the margin of the drop characteristic swallow-tail twins may be found. .0005 mg. of lime can be detected in this way.

A drop of platinum chloride is now added and, if *potassium* was present, strongly refractive octahedrons or trillings or quadrillings appear.

Sodium is detected by cerium sulphate, a saturated solution of which is placed on the slide near the drop to be examined and connected with it by a capillary glass thread. In the drop of the reagent there appear desmid-like aggregates of cerium sulphate and on the margin a brown cloudy zone of double salt of soda. Excess of sulphuric acid prevents the reaction.

Magnesium is detected by salt of phosphorus. The drop, before tested for possium or aluminum, is neutralized with ammonia and in a drop of water placed at a distance of about 1 cm. is placed a grain of salt of phosphorus and the two drops connected as before. The result is the production of double, forked crystalloids similar to those found in natural glasses or well developed hemimorphic twins of ammoniated magnesium phosphate.

Aluminum is detected by touching the drop with a platinum wire dipped in caesium chloride. Translucent octahedrons of caesium alumn are formed, or more rarely $1 . \bar{i}\text{-}\bar{i}$. If the solution of the mineral is concentrated, dendritic forms simply are formed and water must be added.

Similar tests are proposed for the detection of other elements but the above are of most general application.

C. *Use of the Polarizing Microscope.*

Ordinary polarized light is produced by placing the analyzer above the eye-piece in such a position that its Nicol's prism stands at right angles to that in the polarizer below the stage The field now appears totally dark, inasmuch as the only rays permitted to pass through the polarizer are extinguished by the analyzer.

All minerals are either simply or doubly refractive, and the former may be recognized as *amorphous* (like glass) or belonging to the *isometric* crystal system. Inasmuch as the elasticity of the ether in either case will be the same in any direction in such minerals, they do not interfere with the rays which pass through them, hence between crossed Nichols any section of such minerals remains constantly dark, even though the section be passed through a complete revolution by rotating the stage—in other words, the mineral is *isotropous*. Double refractive minerals, in sections taken in some directions, become colored in certain positions between crossed Nicols. Such sections become perfectly dark twice in one complete revolution. These colors are due to interference of the rays brought about by the double refraction.

Optical uniaxial crystals are those falling in either the tetragonal or hexagonal systems. In such crystals there is but one direction in which there is no double refraction, *i. e.* that parallel to the vertical axis c, which, in this case, corresponds to the optical axis. The elasticity of the ether contained in the crystal is different in directions parallel and at right angles to the main axis. $\mathfrak{a}=$ the axis of the greatest elacticity and $\mathfrak{c}=$ the axis of least elasticity. $\omega=$ exponent of refraction in the ordinary ray (that is, the one passing parallel to the optical axis and vibrating at right angles to the fundamental section. $\varepsilon=$ exponent of extraordinary ray (*i. e.* that passing at right angle to the optical axis and vibrating in the principal section. If the axis c coincides with the optical axis $\mathfrak{a}$ and $\omega > \varepsilon$ the mineral is negatively double refractive, while if $c = \mathfrak{c}$ and $\omega < \varepsilon$, the mineral is positively double refractive. A thin section of a crystal of either the tetragonal or hexagonal system, if basal, (*i. e.* parallel to O) acts as though isotropous and remains dark in all positions between crossed Nicols. On the other hand, sections taken vertical to O, or parallel to one of the prismatic faces, are dark twice in a revolution and these points occur when the sides of the section are parallel to the principal section of the Nicol's prisms. In such a case the extinction is said to be perpendicular or parallel to the crystallographic axis. Sections inclined to the vertical axis or such as are parallel to a pyramidal face are extinguisned parallel to the vertical axis, but not necessarily to all the sides. Whether the mineral proven to be uniaxial is hexagonal or tetragonal can only be discovered by ascertaining the number of sides of a section transverse to the vertical axis.

In *biaxial minerals* there are two directions without double refraction. Three axes are assumed, each of which is at right angles to the others and has a different amount of elasticity of the ether. These elasticity axes are lettered $\mathfrak{a}$, $\mathfrak{b}$ and $\mathfrak{c}$, in order of elasticity. Two of the optical axes do not correspond with the crystallographic axes, but the two sets of axes form with each other larger or smaller angles. The line which bisects the acute angle = *acute bisectrix*, that which bisects the obtuse angle = *obtuse bisectrix*. The optical axes and both the acute and obtuse bisectrix lie in the same plane, called the optical plane, perpendicular to which is the optic normal. The axis of intermediate elasticity ($\mathfrak{b}$) coincides with the optic normal, while the axes of least and greatest elasticity may coincide with either bisectrix. If a coincides with the acute bisectrix, then c coincides with the obtuse bisectrix and the mineral is negative. If, on the other hand, c coincides with the acute bisectrix and a with the obtuse, it is positively double refractive. α, β, γ are the indices of refraction corresponding to the three axes of elasticity.

In the case of minerals of the *Orthohombic system* the three axes of elasticity $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$ correspond with the crystallographic axes $\bar{a}$, b, and c, but not necessarily in such a way that $\mathfrak{a}$ always corresponds to $\bar{a}$, etc. a and c are always bisectrices and the optical plane is always parallel to one of the three pinacoids.

The following are possible :

$$\text{If Opt. plane} = \text{O}, \left.\begin{array}{l} \breve{a}=\mathfrak{a},\ b=\mathfrak{c} \\ \breve{a}=\mathfrak{c},\ b=\mathfrak{a} \end{array}\right\} c'=\mathfrak{b}$$

$$\text{If Opt. plane} = \text{i–}\breve{\text{i}}, \left.\begin{array}{l} c'=\mathfrak{a},\ \breve{a}=\mathfrak{c} \\ c'=\mathfrak{c},\ \breve{a}=\mathfrak{a} \end{array}\right\} b=\mathfrak{b}$$

$$\text{If Opt. plane} = \text{i–}\bar{\text{i}}, \left.\begin{array}{l} c'=\mathfrak{a},\ b=\mathfrak{c} \\ c'=\mathfrak{c},\ b=\mathfrak{a} \end{array}\right\} \breve{a}=\mathfrak{b}$$

Sections parallel to one of the three pinacoid surfaces (usually rectangular) extinguish perpendicularly, *i. e.* become dark between crossed Nicols when one side of the rectangle or one of the pinacoid cleavage lines is parallel to the main section of the Nicol. Distinguished from isometric minerals by the fact that basal sections (parallel O) are not isotropous Only such sections are isotropous as are exactly vertical to the one or the other of the optical axes, which would be the case, according to the position of the optical plane, in the plane 1–ĭ, 1–ī or a prismatic surface. Hence isotropous sections are more rare and less regular than in isometric minerals. Sections parallel to the vertical axis in the zone i–ĭ, i–ī extinguish perpendicularly.

In *monoclinic minerals* only the ortho-diagonal (*b*) coincides with one of the axes of elasticity, the other axes of elasticity form angles with a′ and c′. The optical plane is either parallel or at right angles to the plane of symmetry i–ĭ.

$$\left.\begin{array}{l}\text{If optic plane} = \text{i–ĭ the acute bisectrix} = \mathfrak{c}\\ \qquad\qquad\quad\text{or `` `` ``} \qquad\qquad = \mathfrak{a}\end{array}\right\}\mathfrak{b}=\mathfrak{b}$$

then $\mathfrak{c}$ and $\mathfrak{a}$ are inclined toward $\mathfrak{c}$ and ā.

If optic plane is at right angles to i–ĭ.

the acute bisectrix = $\mathfrak{b}=\mathfrak{a}$
" " = $\mathfrak{b}=\mathfrak{c}$
or the obtuse " = $\mathfrak{b}=\mathfrak{a}$
" " " = $\mathfrak{b}=\mathfrak{c}$

then $\mathfrak{b}$ and $\mathfrak{c}$ or $\mathfrak{b}$ and $\mathfrak{a}$ are inclined toward c′ and a′.

As a result of the inclination of the axes of elasticity to the crystallographic axes certain of the longitudinal sections are not extinguished when the crystallographic axes coincide with the principal plane of the Nicol's prism. Sections in the zone O. i–ĭ, all are extinguished perpendicularly, for in this case the orthodiagonal coincides with an axis of elasticity.

In *Triclinic* minerals none of the three axes of elasticity coincides with the crystallographic axes. All sections parallel to the three pinacoid surfaces, therefore, are obliquely extinguished. The angle of extinction in the planes O and i–ĭ is known for most triclinic minerals and forms a ready means of determining these minerals. In thin sections the shape of the section will generally make it clear whether it is or is not parallel to a pinacoid. Accurate measurements of the angle of extinction must be made in cleavage plates parallel to i–ĭ and O.

Twinning Phenomena.

Twins in the regular system cannot be recognized by the polarizer. Twins in the tetragonal and hexagonal systems cannot be recognized unless the axes of the twins are inclined toward each other. If one individual, in such a case, appears dark between crossed Nicols the other may appear colored.

In some cases a crystal individual is made up of alternate lamellæ of the same mineral in different position relative to the axis. Such aggregates are called *polysynthetic twins*. In plagioclase feldspar, calcite and disthene this frequently occurs. In such minerals the adjacent lamellæ will not be extinguished simultaneously under polarized light.

In the rhombic system the twinning plane is usually one surface of a brachydome, a pyramid or a prism. Pleochroism in colored minerals assists in determining the relation of twinned crystals.

In the monoclinic system the plane is often i–i′.

In the triclinic system the polysynthetic form appears very frequently. In plagioclase the twinning plane is generally i–ĭ (albite type). Sections at right angles to this plane in the zone O. i–ĭ always exhibit the banded colors in polarized light. Twins of this type are impossible in the monoclinic system, because the plane corresponding to i–ī = i–ī′ and coincides with a symmetry plane, hence coalescence in this way would not produce twins. A second type is the pericline type in which the twinning plane is at right angles to the zone O, i–ī.

Pleochroism.

Double refracting minerals have the property of affording different colors when looked through in different directions corresponding to the axes of elasticity. In optically uni-axial crystals there are two such directions (*i. e.* the minerals are dichroic) and the color afforded by looking through in the direction parallel to the vertical axis is called the basis color, that appearing when looked through at right angles to this the axial color. A section of a uniaxial crystal will show no change of color when rotated above the polarizer (analyzer being removed) if the section is parallel to the vertical axis.

In tetragonal and hexagonal minerals, therefore, the directions where greatest change of color occur coincide with the two axes of elasticity, in the orthorhombic system they coincide with the three crystallographic axes as well, but in the monoclinic and triclinic this coincidence seems not to occur.

Use of convergent Polarized Light.

The occular is removed and a condensing lense is placed above the polarizer, between it and the object. Interference figures of a nature varying with the character of the mineral now appear. In regular and amorphous minerals no such figures are produced. The same is true of sections parallel to the vertical axis of the hexagonal and tetragonal minerals. In the transverse (isotropous) sections of *tetragonal* and *hexagonal* minerals an invariable dark interference cross lies in the centre of the field. If the sections is oblique, the cross falls at one side of the centre but is not otherwise altered. A rotation of the stage causes the cross to apparently revolve in the same direction. If the section is so oblique as to fall outside the field a rotation will bring first one limb and then the other into view.

A section of biaxial crystals taken perpendicularly to the bisectrices and placed so that the optical plane coincides with the principal section of the Nicols shows two closed curves enclosing the axial points. These curves are bordered by other curves and crossed by a dark cross. The smaller limb of the cross passes through the axial points and indicates the position of the optical axis plane. The broader limb of the cross is at right angles to it. When the stage is revolved the cross does not remain invariable but is altered to form two hyperbolas which move about the axial points and again form a cross after a revolution of 90°.

The above account, condensed, in the main, from Hussak, will serve to introduce the tables, while the student may be referred for more full explanations to the works of Rosenbusch, Zirkle, Fouque′ and Levy, Cohen and especially Hussak's "Anleitung zum bestimmen der gesteinbildenden Mineralien."

D. Recapitulation of characters of the various crystal systems.

1. *Amorphous* and *regular* minerals are distinguished from all others by remaining dark in all positions between crossed Nicols, while the later may be

distinguished from the former, even in sections, by the regular contour and cleavage.

2. The remainder of mineral species are anisotropous. *Tetragonal* and *hexagonal* minerals have different elasticity in directions parallel and perpendicular to vertical axis c. Rectangular or hexagonal longitudinal sections are extinguished perpendicularly. In convergent polarized light transverse sections exhibit a fixed axial cross, while in longitudinal sections no interference figures appear. Sections obique to the axis show lateral displacement of the optic axis. The fixed axial cross appears to move in the same direction as the stage when revolved. *Hexagonal* are distinguished from the tetragonal forms by the hexagonal and twelve-sided transverse sections.

3. The remaining minerals are optically bi-axial, and in those sections which are isotropous a black band appears in convergent polarized light, which appears to move in a direction opposite to the stage. The axial point may lie within or out of the field (depending on the inclination of the section.) If the band (hyperbola) is bordered with red on the convex side and blue on the concave the dispersion of the axes$=\rho > v$, if the reverse $\rho < v$.

Orthorhombic minerals have both optic axes in a plane parallel a pinacoid. In sections at right angles to the vertical axis extinction takes place parallel and perpendicular to the sides. In sections parallel to the vertical axis extinction is also perpendicular. No interference figure in the third pinacoid section in convergent polarized light.

In *Monoclinic* minerals one axis of elasticity coincides with the orthodiagonal, the others in the symetry plane i–ī or perpendicular to it. Sections perpendicular to the vertical axis are perpendicularly extinguished. Sections parallel to the vertical axis if in the zone O . i–i are extinguished perpendicularly, sections parallel to i–ī are obliquely extinguished. If the optical axial plane is parallel to i-ī none of the pinacoid sections exhibits perpendicular displacement of a bisectrix, but the interference figure is displaced toward the vertical axis.

In *Triclinic* minerals neither of the axes of elasticity coincides with the crystallographic axes. The optical axial plane is not perpendicular to pinacoid surfaces. No pinacoid section is perpendicularly extinguished and none of these sections exhibits perpendicular displacement of the bisectrix.

Explanation of Plate XI.

Fig. 1. Diagramatic section of Lithological Microscope as manufactured by Fuess of Berlin. [See text.]

Fig. 2. Reflecting goniometer of Wollaston, for measuring angles of macroscopic crystals.

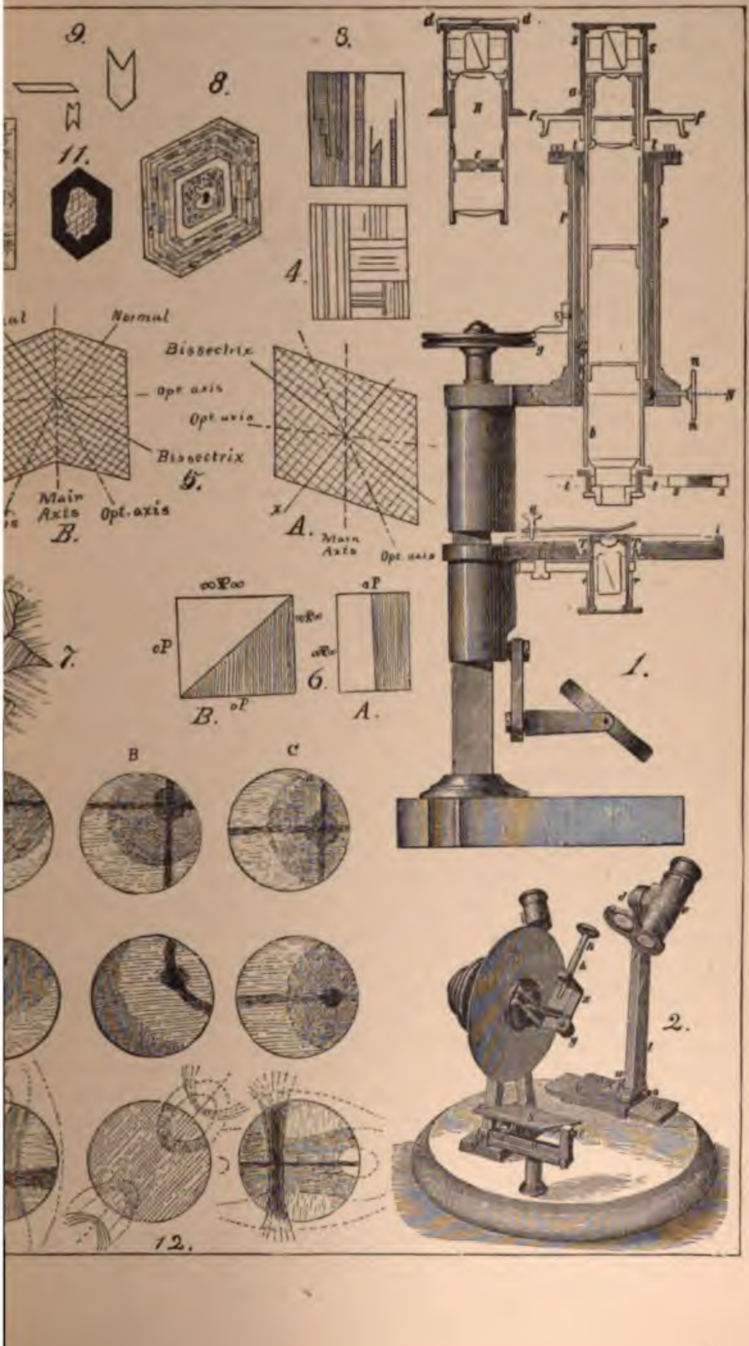
Fig. 3. Polysynthetic twins of plagioclase; section parallel i–ī. (From Hussak.)

Fig. 4. Plagioclase twinned according to both the albite and pericline type; section parallel i–ī. (From Hussak.)

Fig. 5. Diagram illustrating relation of the optical axes etc., in twins. (In Λ x = Normal.) It may be more clearly illustrated as follows:— A thin plate of gypsum is taken parallel the principal clinodiagonal. Out of this a rhombic piece is obtained by using the conchoidal fracture parallel the orthopinacoid and the satiny cleavage parallel to the + hemipyramid. The obtuse angle = 113° 46′ and the acute = 66° 14′. In as much as the optical axes in gypsum lie in the clinodiagonal terminal plane, the surfaces of the plate may be taken as the plane of the optical axes. The conchoidal fracture corresponds with the main axis, and the optical axes above and anteriorly form angles of 23° and 83°. These are represented By bisecting the acute and obtuse angles we may secure the bisectrix (axis of least elasticity) and the optical normal (axis of greatest elasticity) respectively. The bisectrix forms an angle with the longer diagonal of the plate of nearly exactly 20°. Every ray entering the plate perpendicularly is polarized, forming one ray vibrating in the plane of the bisectrix and another in the plane of the optical normal. In a drawing of the exact shape of the plate these lines are drawn and, in addition, the whole area checked into squares by lines parallel to the bisectrix and the normal (on both sides.) The plate is laid upon the drawing and both are bisected parallel the main axis and one piece is revolved 180° and united by its other edge with the second. The result is an artifical twin of gypsum with the optical determinants all indicated in each (Rosenbusch.) The same method may be applied to illustrate other twins.

Fig. 6 A. Orthoclase twins of Carlsbad type.
B " Banover type.
Fig. 7. Polysynthetic twins of calcite in marble.
Fig. 8. Section of augite parallel to i–ī, showing zonary structure. (Hussak.)
Fig. 9. Micro-crystals of gypsum (twinned.)
Fig. 10. Inclusions showing fluction structure.
Fig. 11 Hornblende crystal with opaque altered margin. (Hussak.)
Fig. 12. Diagrams of interference figures in convergent polarized light. (Adapted from Fouque′.)

The polarizer and condensor are used, but the occular is removed and the Nicols are crossed. In regular and amorphic minerals no figure is seen. In *uniaxial crystals* in isotropous sections there appears a fixed axial cross with more or fewer concentric colored rings. These latter vary with the thickness of the section. If the section is not exactly at right angles to the main axis the intersection lies out of the centre and revolves with the motion of the section. If the inclination is still greater the intersection falls beyond the field and a revolution of 90° brings first one and then the other limb of the cross into view, I A a section slightly oblique, I B is the same section revolved 45°, and I C is revolved °90. Biaxial crystals, if taken perpendicular to bisectrix or normal, and if so placed that the opical axis plane coincides with the principal section of the Nicols, show an interference figure consisting of two separate systems of curves whose foci correspond with the two axes. These curves are surrounded each by a lemniscus and a black cross appears with a narrow arm passing through the foci and a broader band between them (II A.) The slender band represents the position of the optical axis plane. When the section is revolved the cross alters its form and at 45° becomes an hyperbola passing about each focus while at 90° the cross reappears but in a position transverse to that formerly occupied.


9.
3.
8.
11.
4.
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Bissectrix
Opt axis
Opt axis
Bissectrix
5.
Main Axis
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TABLES FOR THE DETERMINATION OF THE PRINCIPAL

ROCK-FORMING MINERALS,

Translated and Modified from Hussak's

TABELLEN ZUR BESTIMMUNG DER MINERALIEN.

By C. L. Herrick.

Table of Abbreviations.

c = vertical crystallographic axis.
$\breve{a}$ = brachydiagonal in orthorhombic and triclinic systems.
a' = clinodiagonal in monoclinic system.
b. $\mathfrak{c}$, = axes of elasticity.
ω = exponent of refraction in ordinary ray. } In uniaxial
ε = " " " in extraordinary ray. } crystals.
β = " " " in intermediate axis, }
ρ = " " " in red light. } In biaxial crystals.
υ = " " " in violet light, }
sp. = dispersion of axial points.
Symbols of planes essentially as in Dana's Text-book of Mineralogy.

A. Minerals opaque

Name.	*Chem Comp and reactions.*	*Specif. Grav.*	*Crystal*	*Cleavage.*	*Usual combinations and form of Sections.*	*Twins.*
1. *Magnetite.*	$Fe_3O_4 =$ $FeO + [Fe_2]O_3$. soluble in HCl.	4.9–5.2	I	In the plane 1.	Granular and 1. Quadratic and Triangular.	In the plane 1.
2. *Titanic Magnetite.*	$FeO\left\{\begin{matrix}Fe_2O_3\\ FeTiO_3\end{matrix}\right\}$ Only distinguishable by chem. analysis.	4.8–5.1	I		1 and granular.	as above
3. *Pyrite.*	FeS_2 Soluble in nitric acid separating sulphur.	4.9–5.2–	I	H	½ [i–2] Regular hexagons and pentagons.	Interpenetrating twins ½ [i-2.]
4. *Titanic Iron.*	$FeTiO_3 +$ $+ [Fe_2]O_3$. Soluble in HCl with dif. With salt of phosph. gives reaction for Ti.	4.56–5.21	Hex.	R and OR. conchoidal fracture.	Tabular R.oR also –½ R, –2 R and granular grains elongate rather than rounded. Sections chiefly hexag. elongate. In zic-zacked or reticulated forms.	Axes parallel, Polysynthetic twins in R.
5. *Graphite* (and Bitumen.)	C. Bitumenous black rocks, becoming gray on heating.	1.9–2.3	Hex.	O	Very rare, in thin hexagonal plates and *irregular scales.*	
6. *Pyrrhotite.* See also Chromite, Pleonast, Specular Iron. } beyond	$Fe_n S_{n+1}$	4.54 4.64	Hex.		Irregularly granular.	

even in thinest sections.

Color and lustre.	*Structure.*	*Association.*	*Alterations.*	*Occurrence, etc.*
Iron black, blue-black. metallic lustre	Often in beautiful cruciate aggregates, or, as result of alteration, about a mineral or in its cleavage lines.	With nearly all rock-forming minerals, particularly augite, olivine, plagioclase, nephelin, and leucite.	Very often into limonite, forming a reddish brown band about the crystal of magnetite.	1. As primary necessary component of basic eruptive rocks and accessory in nearly all crystallines. 2. As result of alteration of olivine, augite, hornblende and biotite.
"			Into titanite and limonite (Forms the transition to titanic iron.)	Primary, in basalts and crystalline slates.
In reflected light yellow, metallic lustre			Into limonite.	Rarely as accessory secondary component of altered basic eruptives and (also primary) in crystalline slates.
Blackish brown, metallic lustre. If altered, gray in reflected light		With plagioclase, augite, hornblende, and olivine.	Into titanite and rutile with specular iron.	In basic eruptives, (particularly granular diabases, gabbros, basalt, pikrit); also in crystalline slates. [Distinguished from magnetite by form of sections and alterations.]
Iron black with metallic lustre.				Rarely in cryst. slates, clay and clay-mica-slates, gneiss, limestone; and as inclusions in staurolite, andalusite, chiastolite, dipyre, etc.
Bronze yellow. Metallic lustre.				Very rare in crystalline slates and contact slates Easily distinguished from pyrite in reflected light by the lustre.

B. Minerals transpa-

1. *Minerals crystallizing in the Isometric System.*

Name.	*Chemical comp and reactions.*	*Specific Gravity.*	*Cleavage.*	*Unusual combinations & form of sections.*	*Twins.*	*Color and amount of refraction.*
1. *Hauyn Group.* a. Sodalite	$3(Na_2[Al_2]Si_2O_8)+2NaCl$. Cl reaction. Easily soluble in HCl. leaving a gelatinous residue of LiO_2. On evaporation, cubes of salt.	2.13–2.29	i	Granular and i (rarely 1. H) sections quadratic and hexagonal.	Interpenetrating twins in a trigonal-secondary axis.	Colorless, red from presence of Fe_2O_3, greenish or bluish, *blue.*
b. Hauyn and	$2.(Na_2Ca)(Al_2)Si_2O_8+(Na_2,Ca)SO_4$. Reacts for Ca and H_2SO_4.	2.4–2.5	i	Crystals i and 1 as the above	Twins in 1 & as above	Colorless, blue, black.
c. Nosean.	$3Na_2(Al_2)Si_2O_8+Na_2SO_4$. Reacts for H_2SO_4 Both are soluble in HCl with separation of gelatinous LiO_2	1.279–2.390.		Crystals usually corroded.		Colorless, brown black
2. *Garnet Group.* a Almanadine.	$Fe_3(Al_2)Si_3O_{12}$.	3.78 (3 1–4 2)	Imper. in i	i, 2–2 and granular. Sections quadratic, hexagonal or octagonal.		Red, in very thin secti'ns nearly color- $n_D= 1.772$
b. Pyrope.	$(CaO, MgO, FeO, MnO)Al_2O_3 3SiO_2$ containing chromium.	3.7–3.8	Imper i	Granular.		Blood red-

rent in thin Sections

(See also [illegible])

Structure.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Intimately united with feldspar and hornblende often with a colorless nucleus and red cortical part closed by oxides of iron.	[illegible] augite [illegible]	[illegible] augite.	[illegible]	[illegible]	[illegible]
Very often with a [illegible] tical [illegible] colored differently from the centre which may be darker opaque. Often colored by iron in the fissures	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Often united with quartz or feldspar in micropegmatite	Usually with quartz, [illegible] clase, biotite and hornblende	[illegible] ing the form of the garnet crystal [illegible] Fluid inclusions, quartz grains [illegible] grains [illegible] in [illegible] bands.	[illegible]	[illegible]	[illegible]
	with olivine and augite.	Very poor.	Very characteristic are zones of augite fibres arranged in groups perpendicular to the surface.	[illegible]	[illegible]

Name.	*Chemical Comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of Sec's.*	*Twins.*	*Color and and amt. of refract*	*S*
c. Melanite	$Ca_3\,(Fe_2)\,Si_3\,O_{12}$	3.6–4.3	Incomplete. i	Crystals i		Black, in sections dark brown, quite opaque.	Of h zo tu oft re
3. *Spinel Group.* a. Chromite.	$Fe\,O\,Cr_2\,O_3$	4.4–4.6	Incomplete. 1.	Granular and 1.		Reddish brown, metalic lustre	I gr f ba a l
b. Picotite.	$\begin{matrix}Mg\,O\\Fe\,O\end{matrix}\left\{\begin{matrix}Al_2\,O_3\\Cr_2\,O_3\end{matrix}\right\}$	4.8		1. Very minute grains.	Twins in 1.	Becomes transparent with difficulty	
c. Pleonast.	$\begin{matrix}Fe\,O\\Mg\,O\end{matrix}\left\{\begin{matrix}Al_2\,O_3\\Fe_2\,O_3\end{matrix}\right\}$	Over 3.65 (3.8–4.1)				Dark green	
d. Hercynite.	$Fe\,O.\ Al_2\ O_3$ Insoluble in acids and unaffected by H Fl.			1.		Frequ'nt with quartz, orthoclase, and mica	d
4. *Analcite.*	$Na\,2\,(Al\,2)\,Si_4\,O_{12}+2$ aq. Soluble in H Cl with sep. of $Si\,O_2$ jelly.	2.1–2.28	Incomplete. (According to Tschermak H.)	Chiefly compact granular, in cavities 2 2		Colorless white, $n\rho=1.4874$	fra w tir s g cl b pl
5. *Fluorite.*	$Ca\,Fl_2$. Decomposed by concentrated $H_2\,SO_4$ with liberation of H Fl.	3.1–32	Complete 1.	Occurs in rocks only in the form of minute angular grains.		Blue, colorless. very strongly refractive.	P fe ir d Cl
6. *Perowskite.*	$Ca\,Ti\,O_3$. Decomposed in $H_2\,SO_4$ but not H Cl.	4.0–4.1	II.	In irregular branching and angular forms, generally in distinct octahedrons.	Very rare. Interpenetrating twins.	Violet gray, reddish gray brown. In strong relief.	ro fa ti ec si ili vi c d (p n

Mineral appea

TABLE III.

Association.	*Inclusions.*	*Alteration.*	*Occurrence.*	*Remarks.*
With augite sanidine, nepheline, hauyn, and leucite.	Very poor, augite and apatite needles. glass inclusions.		Primary component of phonolite, leucitophyre, and volcanic products	Compare Titanite.
With olivine and augite.			Primary accessory component in [illegible] rocks, serpentine and basalt.	[illegible] only [illegible] distinguishable.
			Picotite often as inclusions in olivine.	Magnetite is, however, always crystallized, and so easily distinguishable.
Most rarely with olivine and augite.			As grains but rarely, more often in granites and in metamorphic [illegible] rocks.	[illegible] can only be distinguished chemically. The others may be distinguished from magnetite by transparency in very thin sections [illegible]
With plagioclase augite or hornblende.	Poor in inclusions. Fluid inclusions, needles of apatite.		Rare in [illegible] often as alteration product of nepheline. In [illegible] phonolites, trachyte andesites, basalt as alteration product.	[illegible] can only be distinguished chemically
With quartz, orthoclase and biotite.	Fluid inclusions.		Very rare; secondary in quartz porphyry.	
With nephiline, melilite, augite and olivine.	Very poor		In nepheline-leucite- and melilite basalts	Distinguished easily from spinel by color and optical anomalies, and from garnet by its crystalline form.

= Leucite. See below.

II. Double-refractive minerals.

A. Uniaxial optically.

1. Tetragonal system. a. Double refraction positive.

Name.	*Chemical comp. and reactions.*	*Specific gravity.*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Character and amount of double refraction*	*Pola- tion*
1. *Leucite*	$K_2 (Al_2) Si_4 O_{12}$.	2.45–2.5	Incomplete prismatic i-i and O.	Grains and (generally) crystals 1. 4-2. Sections octagons frequently with rounded angles, more rarely hexagons.	2-i, polysynthetic twin striations in these planes, crossing at right or oblique angles.	Small individuals without twin striations appear isotropous. In converg. pol. light no evident axis figure. Double refraction feeble, positive.	Not [illegible]
2. *Rutile* (Nigrine, Sagenite.)	$Ti O_2$. *Ti* reaction with phosphorous bead. Insoluble in acids.	4.2–4.3 (4.277)	I and i-i	I. i-i, 1 granular; generally, however, in minute elongate needles and crystals. The prisms are striated parallel to axis c.	Very frequent and characteristic in the plane 1-i; 'knee shaped' with an angle of 114° 25'; also tissue of fine needles which cut each other at an angle of about 60 (*sagenite*); also cordate twins in 3-i, frequent.	Crystals usually too small for determination with condenser. Double refraction strong, positive.	Ne[illegible]
3. *Zircon*	$Zr O_2$. $Si O_2$. $H_2 SO_4$ decomposes, other acids without effect.	4.4–4.7	Incomplete I and I	I, i-i, 3-3, numerous combinations, almost solely in minute but sharply defined crystals.	Very rare 1-i	Positive, very strong.	Ve[illegible]

II. Double-refractive minerals.

TABLE IV.

A. Uniaxial optically.

1. Tetragonal system. a. Double refraction positive.

Pleochroism.	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence.*	*Remarks.*
	Aggregate of spherical crystals to form a large crystal. Zonal and radiating arrangement of the inclusions. Large corroded crystals of the first order, and minute sharply defined crystals of second order, the latter often penetrating augite	With augite, olivine, plagioclase, and samdine.	Inclusions zonary or radiating, or collected in a central aggregate, consisting of minute glassy particles, gas pores, augite needles, etc as well as of Hauyn, augite, apatite and melaite.	Into an aggregate of colorless or yellowish, finely radiating fibres or grains of zeolites, rarely pseudomorphs of analcite after leucite.	Primary, essential constitu'nt with sanidine etc. in leucitophyres, leucite-tephrites, and basalts, also with nepheline and plagiolase. Only found in later basic eruptives.	The foregoing characters make it easily recognizable unless It occurs in very minute grains in the magma, when it may be difficult to distinguish it from interspersed colorless areas of the glassy basis. In this case to be recognized micro chemically.
Not particularly noticeable	In biotite frequently very regular compounded into "sagenite" forms, also united to titanic iron. Often as an inclusion in the accompanying minerals, particularly garnet and omphacite.	With quartz, potash feldspar, garnet, hornblende, omphacite	Very poor.		As primary accessory component abundant in nearly all crystalline slates, particularly those bearing hornblende and augite, as amphibolites and eklogit's. Also as secondary dec'mposition product of titanic iron. frequent in clay slates.	Easily distinguished from zircon by the polarization colors, color and tendency to twin.
Not noticeable.	Like rutile, one of the first formed components of rocks and therefore frequent as inclusions in the others.	With quartz, orthoclase, biotile, hornblende, augite.	Fluid inclusions, needle-shaped cavities, and long unidentified needles.		Primary accesory component of granite, syenite, quartz porphyry, trachytes and many other eruptive rocks, but rare. More frequ'nt in crystalline slates with rutile.	Well characterized by the crystalline form, polarization colors, and strong double refraction.

b. Double refraction

Name	*Chem. Comp and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinat's and form of the Sections.*	*Twins.*	*Char. and am't of the d'bl. refract*	*Polarization Colors.*	*Color and Amount of refraction*
4. *Anatase.*	As in rutile.	3.83–3.93	O and 1.	Apex 1.		As in rutile.	Like rutile.	Dark, lavender blue.
5. *Mejonite g'p.* a Mejonite.	$Ca_6\ (Al_2)\ Si_9\ O_{36}$.	2.734–2.737.	Complete. i–i	Crystals I. i–i. 1 and large grains or long columnar individuals.		–		$\omega = 1.594$–1.597 $\epsilon = 1.558$–1.561 Colorless, white.
b. Scapolite.	$R_3\ (Al_2)\ Si_6\ O_{21}$ ($R = Ca\ Mg\ No_2$) Soluble in H Cl separating pulverent Si O_2	2.63–2.79				Double refraction negative, rather strong.		$\omega = 1.566$ $\epsilon = 1.545$
c. Couseranite and Dipyre	Similar to scapolite; rich in alkalies, H_2O. Unaffected or but little affected by acids.	2.69–2.76 (2.613) 2.62–2.68	i–i. fracture in O.	Long columus 1 i–i. rounded or frayed out at the end.		As in scapolite, rather strong.	Rather brilliant.	Bluish, in sections, colorless, pelucid; becomes black from inclusions $\omega = 1.558$ $\epsilon = 1.543$
d. Melilite.	$(Ca, Mg. Na_2)_{12}$ $(Al_2\ Fe_2)_2$ $Si_9\ O_{36}$ easily soluble in H Cl with separation of gelatinous silica.	2.90–2.95	Parallel O and I.	Almost always in crystals; thin plates predominatingly O. I. i-i Irregular grains. Sections mostly linear, rectangular or rarely rounded.	Rarely interpenetrating twins with the principal axes at right angles	Feeble.	Not very brilliant, if yellow and fibrous it affords the coloration of an aggreate, if colorless the polarization colors are bluish gray.	Usually citron yellow, *honey yellow*, also colorless, to yellowish white.

negative. TABLE V.

Pleochroism.	*Structure.*	*Association.*	*Inclusions*	*Alterat'ns*	*Occurrence.*	*Remarks.*
Like rutile.		With quartz, orthoclase, biotite			Very rare in granite, quartz-porphyry, and crystalline slates.	
	Scapolite seems to frequently replace plagioclase and to be formed by its decompositi'n	With sanidine sodalite, and augite. With quartz, plagioclase calcite. augite. garnet, rutile, & titanite.	Poor. Fluid inclusions. Rutile occurs in scapolite.	Confused fibrous; changed into calcite.	Primary accessory component, rarely in trachytic rocks. Rare, in crystalline slaties, with plagioclase as a (secondary?) accessory component.	Scapolite is easily distinguished from orthoclase and calcite by its optical peculiarities and cleavage. Mejonite is recognized by its crystal form.
	Crystals in limestone, often very rich in inclusions	With calcite, actinolite and mica	Very rich, particles of carbon, quartz grains, & plates of muscovite, irregularly distribt'd	Fibrous decomposition with formation of calcite in the crevices.	As contact mineral in metamorphic limestone, very rare.	Easily distinguished from andalusite, optically, and from chiastolite by its structure.
Rectangular longitudinal sect'ns show a very feeble dichroism.	Rectangular longitudinal sections show striations and fibrous structure parallel to the shorter side (i. e. axis c); these are very fine spindle-shaped cavities which appear as minute circles when cut at right angles to the axis c, (so-called "spile structure") Coalesced with leucite or pentrating it.	With nepheline, leucite, augite and olivine.	Poor.	The fibrous structure is due to change into zeolitic substances.	As primary ingredient of the nepheline- and leucite-basalts replacing nepheline, often very abundant.	Easily recognized by the crystal form and fibrous structure. Easily confused with nepheline if colorless, but does not show hexagonal isotropous sections. Often only distinguished from serpentine by the light yellow color and the absence of remains of olivine. From biotite distinguished by the lighter color and absence of strongly dichroic longitudinal sections.

2. *Minerals crystallising in*

a. Double refrac-

Name.	*Chemical comp. and reactions.*	*Specific Gravity.*	*Cleavage.*	*Usual combinations & form of sections.*	*Twins.*	*Char. and amount of dbl. refract*
1. *Quartz.*	Si O_2. Insoluble except in H Fl.	2.65.	Incomplete in R. Sections full of cracks due to conchoidal fracture.	Granular or crystals R.–R or iR. R.–.R. Usually in larger individuals. Sections are regular hexagons with two parallel sides longer than the others, or in rhombs, never as microliths.	With parallel axes. Rarely twinned when forming a component of rocks.	Feeble.
1. *Tridymite.*	As above.	2.282 2.326.	Inc'mpl'te ∥ O.	In very minute thin plates O and I.	Frequent. Twinning plane a surface of ⅙ and ¾.	Very feeble.

On account of the minute size of the crystals found in rocks accurate determination is usually impossible. Microscopic tridymite behaves in parallel polarized light as though hexagonal.

the Hexagonal System.

tion positive.

Structure.	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
Often colored by Fe_2O_3 in crevices, or rendered confused by inclusions. Quartz in eruptives often corroded. Coalesces with orthoclase to form micropegmatite frequently in granites. In porphyritic eruptives also sphærolitic.	With orthoclase (and sanidine) more rarely with plagioclase, biotite, hornblende, and augite. Never occurs in augitic olivine-bearing rocks or in nepheline–or leucite bearing rocks as a primary constituent. With muscovite and biotite.	Poor in mineral inclusions Apatite columns. In the fragmental states and granites rich in fluid inclusions and long brownish or blackish curved needles. In eruptives rich in glass inclusions and gas pores.	There are none although changes due to molten magma are not rare in quartz from eruptive rocks See corrosion and secondary glass inclusions.	I. Primary constituent. (a) In eruptive rocks as component of the first order, as macroscopic fragments in grains and crystals in granite with fluid cavities and in quartz–porphyry and trachytes with glassy inclusion, and also as accessory in many other eruptives. As constituent of the second order in the magma of these rocks (b) In nearly all crystalline slates. II. Secondary product by alteration of silicates; in diabase in granular aggregates, and in veins of many rocks. III. In waterworn grains in many clastic rocks. IV. Forming a simple rock, as quartzite etc.	When granular, often deceptively like sanidine, but easily distinguished from isotropic sections of it. Distinguished from nepheline and apatite by insolubility; from corundum by character of double refraction, from calcite by cleavage and twinning.
Usually in aggregates of minute thin hexagonal or irregular superimposed plates. Often in the vicinity of the feldspar or in large masses in the magma.	With quartz, sanidine, plagioclase, augite, biotite, and hornblende. Secondary with opal and chalcedony.	Fluid inclusions.	*Occurrence.* Primary component and secondary in rhyolites, trachytes, hornblende–and augite-andesites. In general, more frequent in later, acid eruptives and more rare in older basic eruptives. Secondary in cavities of these rocks and, in that case, usually in large plates.		Microscopic tridymite may be recognized by the form of its aggergates, while for the larger masses the optical characters serve to identify it.

b. Double refra

Name.	Chemical Comp. and reactions	Specif Gravity	Cleavage.	Usual Combinations and form of the Sections.	Char. and Amt. of dbl. refraction.	Colors of Polarization	Col- Am-
1. *Calcite*	Ca CO$_3$. soluble with effervescence with H Cl. In acetic acid soluble.	2.6–2.8 (2.72)	Incomplete R.	Only in irregular grains and crystal aggregates. Polysynthetic twin marking in −½ R.	Very considerable, negative.	Generally not intense, gray, but brilliantly irridescent like talc especially when in small grains	Col whi g [illegible] Al t fer
2. *Dolomite.*	(Ca Mg) CO$_3$ Less easily soluble.	2.85–2.95	As above.	Grains and R		As above	A [illegible]
3. *Magnesite*	Mg CO$_3$. still less soluble	2.9–3.1	As above.	As above.		As above	A [illegible]
4. *Siderite.*	Fe CO$_3$ easily soluble with effervescence.	3.7–3.9	As above.	As above.		As above	Ye
5 *Nepheline Gp.* a. Elaeolite	(Na K$_2$) (Al$_2$) Si$_2$ O$_8$ Soluble easily in H Cl	2.65 (2.59)	Incomplete large fissures	Only in large grains.		Chiefly bluish green, not brilliant	[illegible]
b. Nepheline	with [illegible]	[illegible]	In[illegible]	H[illegible] and [illegible] In [illegible] O and [illegible] crystals [illegible] laminae and minute irregular grains	Double refraction [illegible] feeble		
[illegible]	[illegible] with [illegible] effervescence [illegible]	2.44 [illegible] 2.454	In[illegible]	Large irregular [illegible]		[illegible]	
[illegible]	[illegible] H [illegible]	2.7 [illegible] 2.8 [illegible]	Very [illegible]	[illegible]		[illegible]	

N[illegible] cleavage, muc[illegible] [illegible] the pla[illegible] [illegible] felspar [illegible] M[illegible] ive. TABLE VII.

ture.	Association.	Inclusions.	Alterations.	Occurrence..	Remarks.
lly in lar ag- ites in ies, in or veins. n irreg- rains & : indi ls be- n the tuents.	In nearly all rocks which bear augite, hornblende, biotite and plagioclase.	Fluid inclusions, very poor in mineral inclusions.	None.	Primary and sole component of limestone, etc. Not known certainly from eruptives except as secondary product, particularly of bisilicates and mica. In crystalline slates as both primary and secondary.	Well characterized by rhombohedral cleavage and twin-lamellation. When in small grains not easily determined Reliance must be put upon the solubility and colors of polarization.
above.					Without the polysynthetic lamellation.
above.	With serpentine.			With olivine and serpentine as product of alteration.	Magnesite and siderite only chemically distinguishable from calcite.
above.	As calcite.			In concentric shells and radiating spheres in andecite, etc., as product of alter'n	
gular coales- ith the constit- nts.	With sodalite microcline, hornblende, and titanite.	Poor, frequently colored green by particles of hornblende.	Fibrous transition into zeolites.	Primary essential component of older eruptives, in elæolite-syenites.	Easily recognized macroscopically. Solubility and Na reaction forming good characteristics.
s'als or gates of e irregu- grains.	With leucite, augite, or with sanidine and augite, or with hornblende and titanite	Frequently augite-microlites arranged parallel to the surfaces.	Usually unaltered in phonolites or polarizing like an aggregate and cloudy, showing passage to zeolites	Primary component of later eruptives, nephelinites, nepheline-and leucite-basalts, phonolites and tephrites.	* See below.
us, coa- d with line and oclase.	As in elaeolite.	Poor, iron oxide flakes, as in elaeolite.	Fibrous decomposition forming calcite. (Cancrinite seems to be but an alteration after nepheline.)	As elaeolite, rare.	Distinguished from elæolite only macroscopically by amt. of $CaCO_3$
as frag- nts in oscopic stals.	With flesh colored orthoclase and mica.		Apparently only a total alteration of nephelin(?) or cordierite(?), largely consists of minute muscovite scales	Rare in orthoclase porphyry.	Easily recognized by crystal form and alteration.

eolites usually show their secondary character. Tridymite has no such short rectangu- igitudinal sections. When nepheline appears as an aggregate of minute grains it can tinguished from colorless glass-masses or quartz or othoclase aggregates by micro- cal methods.

Name.	*Chemical comp. and reactions.*	*Specific gravity.*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins*	*Char. and amount of d'bl. refract*	*Polarization colors*
6. *Apatite*	$Ca_5 P_3 O_{12} Cl$ $Ca_5 P_3 O_{12} Fl$. Dissolves in acids, gives phosphoric acid reaction.	3.16-3.22	Crystals, more rarely granular. Parallel O and I, incomplete. *Fracture* ‖ O very perfect, hence the needles are found broken into sections	I, 1 and more rarely O, generally long columns.		Not strong	Usually not brilliant, as in nepheline.
7. *Corundums.*	$(Al_2) O_3$ Insoluble.	3.9–4	R and oR.	i–2. oR. R and grains. Hexagons and rectangles which are truncated at the angles by R.	Rare in rocks.	Strong.	Very brilliant.
8. *Tourmaline.*	Complicated. Boric acid reaction Not attacked by acids.	3.059	Incomplete R and i–2. Very complete fracture ‖ oR.	Almost alw'ys crystalline R, i–2. ½ (i–R.). transverse sections triangles. hexagons nonagons. Often hemimorphic parallel to main axis, oR below, R above.		Strong.	Rather brilliant between red and brown.
9. *Specular Iron*	$Fe_2 O_3$ Easily soluble in HCl.	5.19–5.28.	R oR. Not characteristic in microscopic individuals.	Tabular plates oR. i–2 and irregular plates.	With axes parallell. Interpenetration twins with re-entering angles.	Not definable on account of occurrence.	Very feeble.
Minerals seeming to crystallize in the Hexagonal System.							
1. *Biotite.* 2. *Chlorite.*	} See Monoclinic System.						

TABLE VIII.

r and unt of raction.	*Pleochroism.*	*Structure.*	*Association*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
lorless, ite. red- h, green black rough merous lusions trans ent as heline 1.657	If colored, with evident dichroism.	In irregular grains or long often slender columns, frequently broken into joints by basal fracture Inclusions. Only as accessory component. As inclusions particularly frequent in bisilicates, hornblende and biotite.	Known to occur in nearly all rocks.	Glass inclusions, gas pores Very characteristic are black or brown needles, or minute grains filling the entire crystal, giving the cross section particularly a remblance to hauyns. Central inclusion of glass etc. often assuming the shape of the crystal.	Always unchanged.	Accessory in nearly all rocks. One of the first minerals to separate from the magma.	Distinguishable from hauyn in the longitudinal section and basal fracture; from olivine by optical peculiarities and fracture.
lorless, *blue*, tted. al brown ough in sions. nds out ll in sec- ns be- strong- refract- =1.768 =1.760	When colored, very strong ω=sky blue ε=sea green	Surface of sections rough. In round grains or short columns. Zonary struct're, blue nucleus and colorless cortical layer.	With quartz, orthoclase and biotite, Pleonast, and andalusite.	Very poor, fluid and glass inclusions; zircon; dusty brown inclusions (in "common corundum.")		Very rare. Contact mineral in metamorphic slates and trachytic ejections.	If granular, similar to apatite yet recognized by colors of polarization.
hiefly bluish gray, own. =1.64 =1.62	Very strong dichroism. ω=dark blue, brown to black. ε=light blue to brown.	Macroscopic and *very minute* crystals, rarely in grains, as in certain metamorphic rocks In granites coalesced with quartz in grains Large individuals often frayed out in a radiating manner at the end.	With orthoclase and muscovite in granite. With quartz, orthoclase, mica and other accessory minerals, such as staurolite and garnet.	Very poor. Fluid inclusions.		Primary component, frequent. Granular, accessory in many crystalline slates and in clastic rocks. Characteristic in contact with eruptive rocks	Easily recognized by crystal form and pleochroism. Distinguished from hornblende by optical characters.
n black th me lic lus e. In n plates, od red, o yel- ish red, brown et.		Only in plates in crevices of minerals by infiltration. *Secondary* except perhaps in basalts.	In nearly all rocks particularly with decomposed biotite, hornblende, augite, magnetite, of which it is a product of decomposition.		Into pulverent limonite	(See under association)	Easily recognized.

II. Biaxial minerals.

1 Rhombic System.

a. *Sections parallel O without interference figures.*

Name.	*Chemical comp and reactions.*	*Specific Gravity.*	*Cleavage.*	*Unusual combinations & form of sections.*	*Twins.*	*Optical determinants*	[illegible]
1 *Olivine* (Crysolite)	Mg_2SiO_4 . Fe_2SiO_4 Rather easily soluble in HCl with separation of gelatinous silica.	3.2–3.4	Complete in i-Ī, incomplete in i-Ĭ, conchoidal fracture In sections usually curved crevices.	Tabular crystals I. 1-Ī. i-Ĭ, hexagonal sections. I 130° 2′ 1-Ī 76° 54′. or large rounded grains.	Very rare 1-Ī and interpenetrating.	Acute bisectrix at right angles to i-Ī ä c b a c′ b	[illegible]

β. sections parallel O with interf

aa. disappearance of p

Name.	*Chemical comp and reactions.*	*Specific Gravity.*	*Cleavage.*	*Unusual combinations & form of sections.*	*Twins.*	*Optical determinants*	[illegible]
1 *Sillimanite.*	Al_2SiO_5 Insoluble.	3.23–3.24	Parallel i-Ī; fracture of thin needles in O.	Columnar. I 111°		Optical axial plane i-i acute bisectrix at right angles [illegible] c′ [illegible] b a a b	[illegible]
2. *Staurolite.*	H_2R_2 . Al_4Si_6 $O_{..}$ R [illegible] Fe Mg Insoluble	3.34–3.37	i-i complete. I incomplete, fracture in O	Rarely in irregular grains, crystals I. i-i. O I 128° 42′.	Interpenetrating twins, vertical axes inclined or vertical, rarely microscopic	[illegible]	[illegible]
3 [illegible]	Mg Si O [illegible]	3.1–3.2 [illegible] 3.153	I [illegible] complete [illegible] longitudinal sections [illegible] fracture O	Long columnar [illegible] cross sections with two [illegible] sides, [illegible] angle		[illegible] a a	[illegible]

s of risa- s	*Color and inex of refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence*	*Remarks.*
bril- than e.	In sections colorless. rarely green. Strongly in relief. $\beta - 1.678$.	Surface of sections rough, changes in the crevices to reddish, brownish, or greenish serpentine and has picotite inclusions. Either well defined crystals or fragments or irregular grains.	With olivine, plagioclase, nepheline, leucite, hornblende, and biotite Almost never with primary quartz or orthoclase	Rather poor. aside from minute picotite octahedrons, glass and, more rarely, fluid inclusions, magnetite	Usually into serpentine, also into a brown, fibrous aggregate. Pseudomorphs of calcite after olivine in picrite. Formation of limonite.	As primary essential component of all basic rock. In olivine stone and picrite, melapyre, olivine-gabbro, olivine norite, olivine di'base Also in certain micaceous porphyrits.	Distinguished from quartz in isotropous sections, from zoisite by crystalline form (not in needles) and colors of polarization. from augite by cleavage. from sanidine by rough surface and brilliant colors of polarization.
es, double refractive positive. **trix (+) in O.**							
bril- ant out as musco	Light or dark yellowish brown, strong relief. $\beta\rho = 1.66$.	In exceedingly slender long needles often numerous or felted in parallel masses in quartz, cordierite. etc.	With quartz or thoclase, biotite, and muscovite.	Very poor; fluid inclusions.		As primary, accessory component of crystalline slates; rare	Distinguished from zoisite by double refraction and polarization colors. from andalusite by double refraction and cleavage.
above.	Light or dark brown. $\beta\rho = 1.7526$.	Large and small crystals. characterized by many inclusions.	With quartz, orthoclase, mica, and garnet.	Minute quartz grains, bitumen, specular iron.		Primary accessory in crystalline slates. particularly mica schist	Easily distinguished by pleochroism.
y bril- t.	Colorless to green, strong relief.	In irregular long columns. Often coalesced parallel to c with monoclinic augite.	With plagioclase, olivine, and monoclinic augite.	Very poor.	Into serpentine with formation of talc. Into basite.	In basic p'rphyritic eruptives as essential and accessory. With olivine stone. Rarely in quartz bearing rocks, as quartz porphyry, diabase porphyry also in gabbro and norite	Distinguished from olivine by fibrous structure parallel to c. It does not occur in minute needles as silimanite. Differs from the following only in absence of iron.

Name.	*Chem. Comp. and Reactions*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Optical determinants.*	*Dou refract*
4. *Bronzite.*	m ($Mg\,Si\,O_3$) + n [$Fe\,Si\,O_3$] Insoluble.	3–3.5 (3.12-3.25)	Complete I and partial in i–ī.	Long columnar I . i–ī . i–ī prevailing. $\frac{2}{3}$, $\frac{2}{3}$-ī, very similar to monoclinic augite	Repeated twinning in $\frac{1}{4}$-ī giving the cleavage plates in i–i a wavy appearance. "Knee"-shaped twins in m–ī in stellate groups occur rarely in porphyritic eruptives.	As in enstatite.	Positi Section paralel to & i-I sh simply open c with tra of Lemni Section perpendi ular to a optical ax show one ring or no
5. *Anthophyllite.*	n $Mg\,Si\,O_3$ + $Fe\,Si\,O_3$ Insoluble.	3.187–3.225	i–ī I i-ī, incomplete.	In foliaceous masses rarely in crystals. Sections as in monoclinic hornblende.		Optical axial plane parallel i–ī acute bisectrix at right angles to O c′=c b=b ă=a	Positive, strong.
					bb.	Disappearance of obtuse	
1. *Hypersthene.* 2. *Protobasite* and *basite.* (See below.)	As in Bronzite but with more iron.	3.3–3.4	I complete i–ī conchoidal fracture i–ī incomplete I = about 92°	Large irregular grains and minute columns with the combinati'n I . i–ī. i–ī, also $\frac{1}{2}$-ī. 2–ī 3.2–3.2.	Knee-shaped twins as in bronzite.	Opt axis plane parallel i–ī obtuse bisectrix at right angles to O acute bisectrix at right angles to i–ī c′—c b=b ă=a Large axial angle.	Parallel to O positive, to i–ī negative, feebler than in mono-clinic augite.

Protobasite (diaclasite) and basite have the same composition as bronzite + H_2O. In sharply defined crystals, columnar grains and irregular scales. Cleavage i–ī and I. Opt. axis plane ∥ i–ī. obtuse bisectrix at right angles to O, the acute bisectrix to i–ī. Specif. grav. of protobasite 3.054. of basite 2.6–2.8; the former is is light yellow, with rather brilliant polarization. In gabbro and porph. augite-bearing plagioclase rocks, changes to basite which is dirty light green, and is always a product of decay of rhombic augite.

TABLE X.

ws ler- ion.	Color and Refraction.	Structure.	Association.	Inclusions.	Alterations.	Occurrence.	Remarks.
ter- ance lors ot arly bril- it as non- inic ite.	$\beta = 1.639$ Dark brown. Slight pleochroism	Partly in large irregular grains in coarsely granular rocks partly in sharply defined crystals in porphyritic eruptives.	With olivine, plagioclase, monoclinic augite, magnetite, as enstatite	Inclusions of brown rectangular plates or opaque needles parallel to i–ī.	Into a green fibrous aggregate as basite with separation of Fe_3O_4 or Fe_2O_3.	As enstatite. Often replacing monoclinic augite as essential. Also in later basic eruptives and coarsely granular older rocks.	Distinguished from augite only by study of transverse section and perpendicular extinction in longit. sections from hypersthene by pleochroism and d'ble. refract., from hornblende and biotite by absence of strong pleochroism.
il- it	Dark brown $\beta p = 1.636$, relief faint strongly pleocroic. Parallel to c greenish yellow, at right angles reddish brown.	Inclusions as in bronzite, longit sections seeming fibrous on account of cleavage.	With olivine, plagioclase, augite. and hornblende.	Minute brown and green regularly arranged scales like mica. Otherwise poor in inclusions, magnetite.		Very rare, accessory as secondary product of decomposition of olivine in gabbro and olivine stone.	Distinguishable from biotite by cleavage amt. of pleochroism and size of axial angle.
trix (+) in O.							
her l- at. . az- .	Light or dark brown, black by inclusions. $\beta = 1.639$ Pleochroism strong Axial colors a = hyacinth red b = reddish brown. c = grayish green. c′ > ă > b.	In large irregular grains in granular older rocks, in small crystals in later porphyritic eruptives.	With plagioclase, olivine, and monoclinic augite.	In the granular varieties innumerable brown or violet rectangular scales in the cleavage lines parallel i–ī. In crystals regularly arranged opaque needles otherwise poor.	Decomposes into fibrous aggregate parallel to axis c′, with dirty brown or green color, as enstatite.	In grains in gabbro, norites, in later eruptives, particularly augite andesite and in feldspathic basalts poor in olivine as primary necessary component and with monoclinic augite.	Distinguished from monoclinic augite only by effects of convergent polarized light, from bronzite by strong pleochroism.

The three rhombic augites—enstatite, bronzite and hypersthene are chiefly distinguished
riation in amt. of iron, accompanying which a variation in angle of the optical axes lying
e plane i–ī. Rhombic augites distinguished from monoclinic by inferior brilliancy of
ization and feebler double refraction. Isotropous sections perpendic. to opt. axis in mono-
augite exhibit two or three rings and bands while the rhombic at most one and also
polysynthetic twinning ∥ i–ī.

; *In sections ‖ to O the axial interf*

aa. Disappearance of the

Name	*Chem. Comp and reactions.*	*Specif. Grav.*	*Cleavage*	*Usual combinations & form of Secs.*	*Twins*	*Optical determinants*	*Double Refract.*	*C*
1. *Andalusite.* Chiastolite is a variety with sp grav. 2.9–3.1, characterized by regularly arranged particles of carbon in the centre and four angles. Occurs in metamorphic slates	$(Al_2)SiO_5$ Insoluble.	3.10–3.17	Prismatic in I. Incomplete in i-I, i-I and 1-I. I 90° 50′. Fracture O	Long columns I . O. 1-I, more rarely granular. Transverse sections quadratic, longit. sections rectangular		Opt. axis plane 1-I. Acute bisectrix O. c a b b a c Axial angle considerable	Negative, strong.	I I
2. *Cordierite.* (Dichroite) Pinite is a decomposition product of the above, consisting of minute fibres and scales.*	$Mg_2(R_2)Si_5O_{18}$ (R_2) Al_2 Fe_2 Almost insoluble.	2.59–2.66	i-I Incomp. 1-I . I 110° 10′.	In large grains and crystals. I . i I O. Hexagonal cross sections, rectagonal longit. sections	Interpenetrating twins multiples in I, more rarely in [illegible]	Opt. axis plane i I Acute bisectrix O c′ a b c a b [illegible]	Negative, feeble	I lu qu

bb. Disappear[illegible]

| [illegible] | H_2 [illegible] Al [illegible] Si [illegible] $O_{[illegible]}$ Soluble with difficulty with separation of gelatinous silica | 3.22–3.36 | [illegible] Very complete Fracture parallel O | Elongated grains and long. transversely jointed columns. I [illegible] I 116° 26′ | | Opt. axis plane [illegible] always a′ [illegible]
b b [illegible]
c′ a [illegible]
when Opt. axis plane O
b a
c′ b | [illegible] | |

*Pinite. Large crystals I [illegible] O. Polarizes as an aggregate of quartz, orthoclase and [illegible]tite. Easily recognized macroscopically by the [illegible] decomposition *sible; durable refraction negative.* *TABLE XI.*

n O negative.

Structure.	*Association*	*Inclusions*	*Alterations*	*Occurrence.*	*Remarks.*
Rarely in grains, almost always columnar like staurolite. Often so full of inclusions as to obscure the andalusite. Often in radiating aggregates of long needles.	With quartz, orthoclase. biotite, muscovite.	Sometimes poor. often as in metamorphic slates, rich in quartz grains, bitumen and scales of biotite	Often into greenish fibrous aggregates	Primary accessory in granite and cryst. slates. as metamorph. mineral in contact schists, etc.	Distinguished from augite by pleochroism and perpendicular extinction; from enstatite by character of double refraction; from hypersthene by color and double refraction, from zoicite by pleochroism, form of sections etc.; more difficult to distinguish from sillimanite which, however, occurs in minute needles.
Never in microlites. In large round grains or small crystals (in eruptive rocks.) A metamorphic mineral.	With quartz, orthoclase, and biotite With quartz sanidine, pleonast, and corundum.	Fluid inclusions, sillimanite needles, pleonast crystals, zircon, glassy inclusions.	Very frequent, particularly when occuring in grains. Changes to a fibrous green aggregate resembling andalusite (pinite).	Rare, as accessory, primary constituent of granite, quartz—porphry (pinite) and in grains in gneiss. Rarely in Trachytes and trachytic volcanics.	In thin sections much resembling quartz, but may be distinguished by the decomposition.

n O (negative.)

The transverse fractures of the long columns is characteristic, also the inclusions.	With quartz, omphacite, garnet mica, and hornblende.	Fluid inclusions are numerous.	Frequently cloudy on the edges.	Frequent in crystalline slates as eclogites and particularly amphibolites.	Easily distinguish'd from apatite by optical peculiarities, from andalusite by cleavage in O, and the pleochroism and colors of polarizat'n. Never microlitic as Sillimanite. It differs from olivine in crystal form, etc.

II. b. 2. Monoclinic minerals.

a. Apparently hexagonal (or rhombic); highly perfect cleavage parallel O

Name.	*Chemical comp. and reactions.*	*Specific gravity*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Optical determinants.*	*Dou fra*
1. *Mica Group* a. Meroxene. (*Biotite*) b Rubelane. Differs in the brownish red or seal red col or from biotite of which it seems to be a pyrogene product of alteration. Occurs in basalts and lava.	Mixture of K_3 $(Al_2)_3$ Si_6 H_3 O_{24} and Mg_{12} Si_6 O_{24} in ratio of 1:1 or 1:2 (Tschermak). Decomposed by H_2SO_4 completely with formation of skeleton of silica.	2.8–3.2	O very perfect Separati'g in −1−3′ and ½ (1−i) correspondi'g to sliding or pressure planes.	I almost 120° I. i−i′ O Thin plates or short columns. Sections parallel to O are hexagonal plates without fracture lines. Often with sliding planes and three systems of lines intersecting at 60°. The longitudinal section rectangular with numerous cleavage lines parallel to axis c′	Rare. Twinning plane I Indivídu'ls distort'd so as to be attached in a plane almost parallel to O. Often int'rlamellated when only recognizable in polarized light.	Opt. axial plane i−i′ and parallel two opposite sides of the hexagon Acute bisectrix a varying little from the perpendicular to O Axial angle usually very small ; − 3°, variable, occasionally large, varying with the amount of iron. Disp [illegible]	Neg App ly pe dical tice small an mal app [illegible]
c *Phlogopite*. Can be distinguished by chemical analysis and the yellow or light brown color A magnesia mica nearly free from iron	According to Tschermak, a		As in meroxene.	As in meroxene.		Optical axis planes i−i′ a almost ⊥ O Axial angle 12–16° Disp [illegible]	Neg Fat perpe [illegible]
d. *Anomite* Biotite-pars[illegible]	mixture of H_2 K_4 $Al_{[illegible]}$ Si_6 O_{24} and Mg_{12} Si_6 O_{24} in ratio [illegible] 2:1						
e. M[illegible] and Seri[illegible]	H_4 K_2 $Al_{[illegible]}$ Si_6 O_{24} In[illegible] uble	2.76–3.1	Very perfect parallel to O Sliding planes	Rarely crystallized in rocks. Six sided plates	As meroxene	[illegible] Dis [illegible] 70	[illegible]
2. T[illegible]	H_2 $Mg_{[illegible]}$ Si_4 O_{12} Unaffected [illegible] [illegible] Alkaline reaction	2.60–2.8	Perfect O, in complete [illegible]	Never in crystals, in rocks usually as minute irregular plates like mica		Optic [illegible] plane [illegible] almost [illegible] to O.	Neg [illegible]
3. *Chlorite Group* a. R[illegible] [illegible] Sen[illegible] and [illegible] pla[illegible]	Mixture [illegible] 2H [illegible] 3Mg [illegible] SiO_2 [illegible] 2H [illegible] Mg [illegible] Al [illegible] Si O_2	2.7 [illegible]	Perfect O	Scales and hexagonal plates [illegible] O as though hexagonal [illegible] I [illegible]		[illegible] hex [illegible] axial [illegible] small axial angle a ⊥ O	Neg [illegible]

rs of risa- n	*Color and index of refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence*	*Remarks.*
par ularly liant. wns. thin es ir- scent, nine	Brown black. dark green $\beta=1.61$. Pleochroism strong in long't. sections a and b nearly alike In sections parallel to c—axis a = yellow-bright brown, at right angles *c* c = brown-black. $c>b>a$.	Primary, as large crystals (in eruptive rocks) frequently fragmentary or with opaque margin, (comp. of first order); also in minute scales particularly in crystalline slates or scattered through the magma, as in basalts, etc. (comp of second order.	Usually with quartz and orthoclase, also with hornblende, and more rar'ly with augite and olivine.	Generally free from inclusions, but not rarely with fasciculate masses of epidote needles or regularly arranged slender needles of rutile.	Into chlorite like mineral, with epidote and calcite Loses its brown color, becomes green, calcite penetrates between the scales. needles of epidote appear. Also formation of limonite or magnetite on periphery.	In nearly all rocks. In many as necessary primary constituent, one of the first to appear of the minerals. Product of alteration of augite, hornblende, rarely olivine. Contact mineral in metamorphic slates	Easily recognized by the cleavage and strong pleochroism Cross sections not pleochroic as hornblende. Not green as chlorite. nor fasciculate.
erox-	Red-br'wn Pleochroism feebler than in meroxene.		With olivine and actinolite.		Becoming green to colorless, as above.	Rare in olivine store.	
bril- irrid- , red low.	Colorless, light green oll green.	As primary in large plates In fasciculate and radiate aggregate. As secondary in aggregates of minute irregular scales In crystalline slates.	With quartz, orthoclase tourmaline.	Very poor Rarely needles of rutile. plates of specular iron, or columns of tourmalin, or Zircon.	*Occurrence* Primary in granites (in particular in tourmaline granites) and crystalline slates, as gneiss, mica schists and slate. In no other rocks primary but as product of alteration in feldspars. chiastolite. liebenerite. etc.		Difficult to distinguish microscopically from talc. Sericite is but an unctuous, inelastic, light green muscovite. which occurs in irregular scales in certain crystalline slates.
	Colorless, white, light green.	Usually in irregularly felted or rosette-shaped radiating aggregates of minute scales.	With quartz, orthoclase, mica or with augite and olivine.	Very poor, biotite, actinolite. As muscovite.	A primary constituent in many crystalline slates Not abundant Secondary product of decomposition of augites poor in iron and hornblende, particularly Enstatite altered to olivine stone and serpentine.		Microchemical treatment of isolated scales with fluorosilicic acid is the surest test
very unt,	Light to dark green $u=1.575$. Pleochroism feeble	Not in large scales but like talc as aggregates of minute irregular scales radiate or disperse.	With quartz, orthoclase, biotite muscovite as primary const.	Poor. hematite and limonite, needles of actinolite and rutile	Primary in chlorite slate Decomposition product of mica, augite. hornblende and garnet		Also helminth, pennine. kaemmererite chloritoid, sismondine, and ottrelite. Rare.

2. Crystals

aa. Optical axis plane - i-i', p

Name.	*Chem. Comp and Reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations and form of sections.*	*Twins.*	*Optical determinants.*	*Doul refra*
1a *Orthoclase*	$K_2(Al_2)Si_6O_{16}$. Not attached by acids.	2.50–2.59 (2.57)	Very perfect Between O and i-i' angle 89° 40'	In grains or columnar, O . i-i' . I . 2-i 2-i' . 1 . Sometimes tabular or more rarely, in minute crystals. 1 i' I . O . 2-i . 1-i .	Frequent. (1) Oftenest according to Karlsbad type. Twinning plane i-i (2) Baveno type. Twinning plane 2-i'. (2) Rarely Manebach type.	Optical axis plane inclined to O forming an angle of 5° 11' with vertical axis c b a : a 5° Real axial angle 69°. In sections 1-i' or i-i a distorted biaxial interferance figure visible in convergent pol. light	Negat rath strong In sect 1-i' directio extinct varies the ang O a by c' Section i-i or O extingu perpe: clari
1 b. *Sanidine*			As above. Full of rifts	In slender rods or large crystals, almost never granular. Sections O and i-i elongate bands truncate or acute at the ends. i-i' distorted hexagons with sides corresponding to O . I . i-i. In the columnar type, sections rectangular if perpendicular to O . i-i', if 2-i' is present octagonal.	Twinning plane O	If parallel b a	

clinic Habitus.

nge ‖ O and i–i′; angle about 90°.

TABLE XIII.

rs of triza-ion.	*Color.*	*Structure.*	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
ther liant, ; less n as artz. thin tions ten bril-nt. ish as in eline	Generally cloudy white or gray. rarely clear. Colored red by limonite.	In large crystals or grains of the first order, more rarely in small grains or rods in eruptive rocks. Often coalesced with plagioclase. Zonary structure is rare as is zonal arrangement of inclusions.	With quartz, biotite, muscovite, hornblende and rarely with augite. plagioclase and elæolite.	In general poor. Specular iron, biotite scales, fluid inclusions, needles of apatite, zircon.	Kaolinization with formation. of muscovite or epidote.	One of the most abundant components in granular and porphyritic older eruptives. Essential comp. in granite, syenite. quartz porphyry and accessory in nearly all plagioclase rocks. Also in crystalline slates as gneiss. here often glassy like sanidine	Large crystals may be recognized by twinning in sections parallel to O and i–i and by the oblique extinction parallel i-i′. Minute rods of it and sanidine in the magma of rocks often greatly resemble nepheline and certain melilites, Orthoclase lacks, however, the isotropous hexagonal sections
	Colorless clear. $\beta\ \rho = 1.5237$	In eruptive rocks as large crystals of first order and minute rod second order The large crystals often fractured. Zonary structure.	As orthoclase also with nepheline and leucite but never with muscovite.	Very rich. Glass inclusions, usually zonal in arrangement. augite microlites and needles of apatite	Almost always unaltered, Into opal in andesites and trachytes	Essential comp. (primary) in trachytes, rhyolites, phonolite, and the glass of orthoclase rocks. In nearly all later plagioclase rocks.	From plagioclase it may be distinguished by absence of the polysynthetic twins of the latter.

bb. Optical axial plane ∥ i–i′; perfect cleavage in I ∧ 87°.

Name.	*Chemical comp and reactions.*	*Specif. Grav.*	*Cleavage.*	*Unusual combinations & form of sections.*	*Twins.*	*Optical determinants.*	[illegible]
1 *Monoclinic Augite Group* a. *Common and basaltic augite.*	$R Si O_3$ R = Mg, Ca, Fe, and $Fe_2 O_3$ $Al_2 O_3$ According to Tschermak a mixture of $Ca Mg Si_2 O_6 \cdot Ca Fe Si_2 O_6 \cdot Mg Al_2 Si O_6$ Scarcely attacked by acids.	3.17–3.41 3.34–3.38.	Perfect I	Rarely in grains crystals I, i–i, i–i′ 1 and 1–i. O, I ∧ I 87°6′ Sections perpendicular to c octagonal with evident prismatic cleavage. Longitudinal section distorted hexagonal, with cleavage lines parallel to i–i′ quadrangular often rhombic.	Very frequent. twinning plane i–i, also in polysinthetic twins. More rarely interpenetrating twins in a plane of —1–i or 1–2′.	Optical axis plane i–i′, acute bisectrix c in the obtuse angle of b b′. The positive axial angle enlarges with the amount of iron in rhombic augite, about [illegible]° Sections i–I and perpendicular to c show the disappearance of an optical axis in almost the middle of the field.	[illegible]
b. *Diallage.*	do	3.23–3.34	I(87°), shelly fracture in i–i		do	do	
Omphacite	do with more $Al_2 O_3$	3.3	As in augite fracture less perfect than in diallage	Only in grains	rare	[illegible]	
d. *Di[illegible]*	more Ca than Mg [illegible] $Al_2 O_3$	[illegible]	Less [illegible] than [illegible] above.	More [illegible] as in augite.	do	do	[illegible]

rs ler- im.	*Color and Refraction*	*Structure.*	*Association*	*Inclusions.*	*Decomposition.*	*Occurrence.*	*Remarks.*
ry l. at. ie- ly he pt or-	In section green to brown, often violet brown in basalt. The same crystal often exhibiting several colors. **Pleochroism usually feeble. In phonolite it may be strong. c > a > b.**	In large crystals (I. O.) with zonal alt'rnating colors. In twins these bands pass through both. Often with so-called "hour-glass" form, when sections parallel to i–i fall into 4 areas. Also in columns and microlites (II.O.) crystals often in large aggregates & radial groups	Chiefly with plagioclase, nepheline, leucite, with or without olivine and biotite. Rarely with orthoclase, hornblende, and quartz.	Abundant glass inclusions, apatite needles and magnetite.	Into chlorite, calcite, limonite, epidote and quartz, ps'udomorphs of any of these after augite. Into opal. More rarely into hornblende, the form being retained but the cleavage that of hornblende. Into serpentine with talc and chlorite.	Later porphyritic eruptives as essential and primary, in diabase, augite andesite, and all basalts, also andesites, trachytes, phonolites Rarely in large grains in older eruptives and crystalline slates.	Easily recognized by obliquity of extinction of c: c. the prismatic cleavage with angle of 87°, especially in cross section. Liable to be confused with hornblende in sections inclined to c. When augite is nearly colorless its polarization colors are vivid and like olivine.
,	Greenish brown. Pleochroism very feeble.	Only as large irregular grains. In inclusions, in fibrous and twinning characters much as bronzite. Often coalesced with ordinary augite, hornblende or mica.	With plagioclase, common augite, olivine, hornblende, and rarely with quartz.	Like bronzite with inclusions of brown scales of goethite? parallel to i–i. otherwise poor in inclusions.	At the ends changes into dark green strongly pleochroic hornblende fibres. Into viridite, also serpentine with formation of chlorite and talc.	Primary abundant in gabbro, norite, rare porphyritic eruptives In olivine stone and serpentine. Rare in crystalline slates.	Often similar to bronzite in sections or plates parallel to i–i easily recognized.
o	Grass green.	Only in unaltered gr'ins poor in inclusions. Often coalesced with hornblende.	(c) With quartz, hornblende, garnet, zoisite, disthene, and rutile.	(c) Rare, fluid and rutile needles.		(c) In eclogite and amphibolite	Colors lighter than in augite proper (less iron). Differ from diallage in absence of complete fracture in i–i.
o	do		(d) With olivine, chromite, diallage, & rhombic augite.	(d) Rarely glass inclusions.		(d) In olivine stone (primary) rarely secondary alteration of garnet.	
ry il- at-	**Light green—colorless. Relief strong.**		**(e) quartz, hornblende, scapolite, plagioclase, and titanite.**			(e) In crystalline slates.	

Name.	*Chem. Comp. and reactions.*	*Specif. Grav.*	*Cleavage*	*Usual combinations & form of Secs.*	*Twins*	*Optical determinants*	*Double Refract*	*Ca Pa*
f. *Acmite.*	Na_2 (Fe_2) Si_4 O_{12}	3.53–3.55	Complete I 87°, incomplete i-i.	In grains or long flattened columns (planes i-i being largest) I . i-i . i-i′	i-i frequent	As augite	As augite.	, a Pa ma er c- be
g. *Wollastonite*	Ca Si O_3 Completely decompos'd, separating galatinous silica.	2.78–2.91	Parallel i-i, O and 1-i	I 87° Almost always in irregular fibrous long prisms	do	Opt. axis plane ⊥ i-i′. Apparent axial angle 70°	Positive, strong. c forms an angle with O of 32° 12′ a : c 12°	bri g c bri
							cc.	Ca
2 *Hornblende Group. Common & Basaltic Hornblende* [[illegible] *Smaragdite.* Compare uralite. Occurs with omphacite, garnet, zoisite and rutile.]	mRSiO_3 + n(R_2)O_3 . R = Ca, Mg, Fe. R_2 = Al_2, Fe_2. When containing much iron, attacked slightly by acids.	3.1–3.3	I very perfect with angle of 124° 11′. i-i and i-i′ imperfect	I . i-i′ . i-i and O . 1 or 1-i′ almost always in crystals. Cross sections usually hexagonal, also octagonal, longit. sections as augite.	Frequent i-i	Opt. axis plane i-i′. Acute bisectrix a falls in the obtuse angle [illegible] Real axial angle about 79° Positive axial angle varying with amt of Fe. Opt axis disappears on edge of field O and [illegible]	Negative, rather less strong than augite Extinction [illegible] in green [illegible]	br th a ve
[illegible]	Ca Mg_3 Si_4 O_{12} (Ca Fe) Si_4 O_{12}. [illegible] Na Al little iron	3.026–3.10	As above, fracture transverse	Long columns usually not terminated I [illegible]	More rarely	[illegible]		
d [illegible]	3MgSiO_3, CaSiO_3, Preponderating MgO [illegible] See text [illegible]	2.93	I as above	I . i-i Long slender columns			[illegible]	[illegible]

TABLE XV.

etc.	Structure.	Association	Inclusions.	Alterations.	Occurrence.	Remarks.
k n– c n ver '.	In large crystals in syenite, often frayed at the end. In minute crystals yellow or dark green in trachytes and phonolites.	With elaeolite, sodalite, microline, and biotite.	Metallic particles.		Not rare in elaeolite–syenite, Phonolite, and trachytes.	
less rish e. ig f.	In fasciculate or radiate aggregates.	With calcite, green augite, granite.	Fluid inclusions.		(g) as product alteration of contact mineral rare in granular limestones, which have been the result of metamerphism. Rarely in phonolite etc.	(g) Very similar to tremolite, distinguished by angles of the prisin and solubility. Difficult to distinguish from zeolitic substances as scolezite.
ge I=124°.						
n- rn. .62 hro- ith- ong el- h or y w. l- sh n. ck en- wn a.	In large crystals or grains I . O . rarely in small crystals and microliths II.O . Green hornblende often fibrous, brown zonal. Green hornb. often coalesces with augite.	With orthoclase plagioclase, quartz, biotite rarely with augite and olivine.	Poor. Fluid inclusions, glass and gaspores. Metallic particles and apatite needles.	Yellowish fibrous, epidote, calcite and limonite. Often on the surface to magnetite as augite. Into biotite, chlorite.	Primary essential in granular and porphritic eruptives, as syenite, diorite (green) porphyrite, andesite, trachyte (brown). Accessory in besalt (brown) olivine stone (green) rare. In crystalline slates (green) abundant Essential in amphibolite slates and certain gneiss.	Distinguished from augite by prismatic cleavage angle. slight inclination of c : c and strong pleochroism. Biotite has not the cleavage and dichroism in sections parallel O.
to c n. ro-	Needles or grains often fibrous.	With quartz, mica, chlorite and rutile.	Very poor.	*Occurrence.* (c) Rather frequent in certain crystalline slates lacking feldspar as talc–mica–and chlorite–schists and in serpentine.		(c) Almost always in long columns not in short crystals as in ordinary hornblende.
er rk i. l- h. ss	In columns and fasiculate aggregates.	With calcite, olivine, hornblende, and diallage.	"	(d) As contact mineral in limestone. As primary (rarely secondary) component in slates and serpentine.		(d) compare wollastonite.

(e.) *Arfvedsonite* $Na_2 (Fe_2) Si_4 O_{12}$. Specif. gr. 3.33–3.59. Occurs in la grains cleaving in I, with orthoclase, microcline, elaeolite and sodalite, rarely in elaeo rocks. It is distinguished from hornblende by blue-green color and composition

(b.) *Glaucophane.* $Na_2 (Al_2) Si_4 O_{12}$ with Ca Mg. and Fe. Specif. gr. It is an indigo blue mineral with strong pleochroism occurring in long fibrous [illegible]

dd. Cleavage O and i-ī, angle [illegible]

Name.	*Chemical comp. and reactions.*	*Specific gravity*	*Cleavage.*	*Usual combinations and form of sec's.*	*Twins.*	*Optical determinants*	[illegible]
Epidote.	$H_2 Ca_4 (R_2)_3 Si_6 O_{26}$.	3.32–3.5	O perfect and i-i forming angle of 115° 24′	Extended in the ortho-diagonal, generally small columns I. O. 1-i. i-i Longitudinal sections 1-i′ hexagonal Cross sections O: i-i elongate quadrangular or extended hexagonal. Also in grains.	Plane i-i Rarely microscopic.	Optical axis plane i-ī′ b b acute bisectrix a nearly coincides with c. Sections [illegible] to i-ī show a biaxial interference figure.	Negat strong Extinc a a [illegible] 20°, c á 47′ [illegible]
Titanite.	Ca Si Ti O_5. Decomposed by H_2SO_4, TiO_2 is dissolved, and gypsum formed	3.4-3.6	I 133° 55′ 1 i′ 113° 30′, imperfect.	Usually crystalline I O. [illegible] Or in wedge-shaped grains.	Rather frequent Contact [illegible] or interpenetrating [illegible] twins [illegible]	Optical axis plane i-ī′ acute bisectrix [illegible] dispers[illegible] plane O axes.	Posit strong [illegible]
Gypsum	Ca SO_4 2 Aq. Soluble in acids with difficulty.	2.2 2.4	Complete in the clinodiagonal, less so [illegible]	In grains or long columnar individuals. Crystals I [illegible] 1 i′ [illegible]	Rare in microscopic individuals	Optical axis plane [illegible] Acute bisectrix [illegible] One optical axis [illegible] forming with [illegible] an angle [illegible] 52, the other an angle [illegible] 22	[illegible]

ee Cleavage imperfect in

coalesced with hornblende, rarely in crystalline slates, eclogite, amphibolite, mica hlorite-slates.

g.) *Uralite* (Smaragdite in part) has the composition of hornblende but has a **ige** similar to augite. It is a product of the decomposition of augite and diallage. **:urs** in gabbros and serpentine as well as augite porphyry.

TABLE XVI.

rs of riza- n.	*Color and index of refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alterations*	*Occurrence.*	*Remarks.*
bril- yel- red.	Citron yellow, yellowish green. $\beta = 1.72-1.75$ Pleochroism rather strong in thick columns. $\mathfrak{a}$ = pale yellow, $\mathfrak{b}$ = yellowish green $\mathfrak{c}$ = greenish yellow $\mathfrak{b} > \mathfrak{c} > \mathfrak{a}$.	In long minute columns in chloritic substance or in pseudomorphs, rarely in grains.	With quartz, orthoclase, plagioclase, hornblende, biotite, augite and chlorite,	Very poor. Fluid inclusions.		Secondary frequently as decomposition product of feldspar, hornblendes, biotite, rarely of augite in eruptives & crystalline slates. In the latter also as primary	Similar to augite. Characteristic is the yellow color, strong refraction and vivid colors of polarization.
acute wedge-shaped sections.							
bril-	Faint yellow, reddish brown to colorless. Pleochroism rather strong in dark varieties, $\mathfrak{a}$ = reddish brown, $\mathfrak{c}$ = greenish yellow	Surface of section rough. One of the first minerals to form in eruptive rocks.	With quartz, plagioclase, hornblende, augite, biotite, chlorite, quartz and other accessory minerals.	Very poor.	Rarely pseudomorphs of calcite after titanite.	As primary accessory in eruptives, granite, syenite, phonolite, schists, etc. Andesite, diorite.	Easily recognized by the wedge-shaped sections and rough surface.
bril- , ir- ent.	Colorless or colored by iron.	In minute grains and needles, rarely in crystals.	Rarely with clastic components, as quartz grains or scales of mica.	Fluid inclusions.		As a simple rock, granular or massive.	

II. b. 3. Tric

a. Elongated columnar crystals, colorless or

Name.	*Chem. Comp. and Reactions.*	*Specif Grav.*	*Cleavage.*	*Usual combinations and form of sections.*	*Twins.*	*Optical determinants.*
Disthene. (Cyanite)	$(Al_2)SiO_5$ Insoluble.	3.48–3.68	Very Perfect. i-Ī. Perfect i-I and O.	Grains or columns i-Ī . i-I with an angle of 106° 15′, rarely terminated. Cross section quadrate, or hexagonal of i′-1 or i-1′ is added.	Frequent. Less so microscopic. Either multiples in i-Ī or (2) perpendicular to c axis, or (3) to b axis, or (4) parallel to O.	Opt axis plane makes an angle of 3[illegible] with the angle i-Ī : O, with the angle i-I : O an angle of 60° 15′ and, like the acute bisectrix a stands at nearly a right angle with i-I, parallel to which plane sections show a biaxial interferance figure with negative bisectrix

b. Broad tabular crystals or grains, o

Name.	*Chem. Comp. and Reactions.*	*Specif Grav.*	*Cleavage.*	*Usual combinations and form of sections.*	*Twins.*	*Optical determinants.*
Triclinic Feldspars						
1. ***Microcline*** (fibrous orthoclase.)	As orthoclase	2.54–2.57	Perfect O. quite perfect, i-Ī, i′-1, i-1′.	As orthoclase i-Ī . O . i′-1 i-1′ predominating.	Rare, i-Ī and at right angles to it. Almost always interlammellate with orthoclase giving in sections O the characteristic "lattice structure". Also polysynthetic twins with albite, so that the O [illegible] surfaces are parallel in [illegible] b.	Opt axis plane, almost [illegible] O, its section with i-Ī forms with the obtuse angle O : i-Ī ≤ 6° in the obtuse angle ac cleavage plates in i-Ī show one axis evidently, the axial plane [illegible] oblique [illegible]
2. ***Plagioclase Feldspars*** (a) Albite (Ab)	$Na_2Al_2Si_6O_{16}$ Traces of Ca and K. Not attacked by acids. SiO_2 68%	2.61–2.63	Complete O and i-Ī, incomplete i-I′ and [illegible] Angle O : i-Ī at the right 93° 36′	i-Ī . O . i′-1 [illegible] i-1′ [illegible] Very similar to orthoclase.	*Twins.* Almost always twinned (1) Albite type [illegible] generally polysynthetic; often two such polysynthetic individuals are again twinned according to the Carlsbad type (2) Pericline type and these again united on the Manebach type (3) By a union of (1) and (2) there results a lattice arrangement reminding of microcline	Opt axis plane [illegible] an angle [illegible] with [illegible] the [illegible] at 16°–17° [illegible] [illegible] cleavage plates [illegible] interference [illegible]

rals. *TABLE XVII.*

anular.) Cleavage in i–ī, i–ĭ, and O.

uble ction.	*Color, etc.*	*Structure.*	*Association.*	*Inclusions.*	*Alterations.*	*Occurrence.*	*Remarks.*
ative, *ong.* nction ctions i–ĭ =36° $< \rho$	Colorless or sky blue. $\beta\rho = 1.72$ strong relief. If blue, with rather strong pleochroism. c=blue a=white	In long columns or irregular grains with crevices ‖ or ⊥ to axis c. Often completely or mottled blue. Rarely in aggregates of needles.	With quartz, mica, garnet, omphacite, hornblende rarely with orthoclase.	Poor. Fluid inclusions.	Rarely margined. by a zone of alteration.	Rare as primary accessory in crystalline slates granulite, eclogite and mica schists.	If colorless, only to be distinguished from sillimanite by position of axis of elasticity.
age parallel to O. and i–ĭ.							
ative, ther ong. plates llel to ositive. nction perpen- lar but que in s par- l to O.	Colorless Relief not strong, as in orthoclase.	In rocks only as grains, often coalesced with quartz, as in graphic granite.	(a) With orthoclase, elaeolite, sodalite, augite, and hornblende (b) With quartz, orthoclase, biotite, hornblende & muscovite (c) With the above and garnet and cyanite.	Usually very poor. Hornblende biotite, zircon, apatite	Similar to that of orthoclase.	Primary essential with orthoclase in (a) elaeolite–syenite. (b) in various granites particularly in graphic granite (c) Crystalline slates as granulite and gneiss.	Easily distinguished from orthoclase by extinction oblique to O and twinning; from other triclinic feldspars by latticed twinning and optical peculiarities.
itive, ther g. In avage tes ‖ O nction lined h the le O : i–ī 54′– 51′; i–ĭ ° 33′– °.	Colorless clear, slight relief. $\beta\rho = 1.537$	In large grains, rarely in crystals, often coalesced with orthoclase and quartz In eruptive rocks in slender rods.	With calcite, quartz, mica and orthoclase, also chlorite and more rarely hornblende	Very poor, fluid inclusions.	Rarely altered. Becomes cloudy as orthoclase.	In granular limestone, frequent. In crystalline slates. In many semi-crystalline gneisses, phyllite, sericite slate. Rarely in eruptives, in grains in diorites, in rods in andesites and porphyrys.	All plagioclase is characterized by the polysynthetic twinning. Triclinic feldspars can only be distinguished by chemical means or determination of direction of extinction etc. Even then only in rather large grains.

Name.	*Chemical comp. and reactions.*	*Specif. Grav.*	*Cleavage.*	*Usual combinations & form of sections.*	*Twins.*	*Optical determinants.*	[illegible]
b *Oligoclase.*	Si O₂ 62–66%. A little K (Ab₃ An₁ Ab₅ An₁.)	2.62–2.65 (2.63.)	Most perfect, O, also i-Ī as albite. O: i-Ī 93° 28′ at the right.	As albite.	Always polysynthetic, of the albite type; also of pericline type	Very similar to albite. In cleavage plates [illegible] the axial points lie farther out of the field of view than in albite [illegible] inclined to the obtuse angle O: i-Ī	[illegible]
c *Andesite.*	R Al Si₄ O₁₂. R = Na₂ and Ca. (Ab₃ An₁ to Ab₁ An₁.)	2.65	do	As albite	As albite Often with the albite and pericline type combined.	Similar to oligoclase but the axial plane is more than 15° inclined to obtuse angle O: i-Ī. Disp. ρ [illegible]	[illegible]
d. *Labradorite.*	R Al Si₃ O₁₀ (Ab₁ An₁ to Ab₁ An₃). Attacked by HCl	2.68–2.70	As orthoclase in i-ī often with a play of colors	Usually in large grains, rarely crystals, as orthoclase.	Individuals twinned i-i are again twinned according [illegible]	In surface i-ī, lateral disappearance of one axis and signs of [illegible]	[illegible]
e *Bytownite.*	A mixture Si O₂ [illegible] 45% Ab An₃ An. More easily decomposed by HCl	2.70–2.73 (2.71)	do	do	do	[illegible]	[illegible]
f *Anorthite.* [An]	Ca Al₂ Si₂ O₈. Si O₂ 43 [illegible] Soluble in HCl with formation of gelatinous silica	2.73–2.75	Complete O and i-ī [illegible] at right [illegible]	As albite	As albite	[illegible]	[illegible]

TABLE XVIII.

rs ar- on.	*Color and Refraction.*	*Structure.*	*Association*	*Inclusions.*	*Alteration.*	*Occurrence.*	*Remarks.*
al- .	Colorless, clear or cloudy, white to gray.	In large grains or crystals of I.O. and in minute slender rods (sections of thin plates. Zonary structure and arrangement of inclusions. Twinning and concentric arrangement (as in orthoclase) both present.	With quartz, orthoclase, hornblende, biotite, augite and olivine.	Fluid (rarely) and frequently glass inclusions in later eruptives; augite and apatite microlites	Usually unaltered in later and cloudy-fibrous in earlier eruptives Change into epidote ("saussurite") also to muscovite as in orthoclase and nearly all plagioclase.	Primary essential or accessory in eruptives. granite, diorite, diabase, gabbro, trachyte, andesite, also in basalt, and crystalline slates.	As albite.
al- .	do	do	With sandine, orthoclase, augite, hornblende, biotite and quartz.	do	Usually unaltered.	Primary essential in tonalite (quartz diorite), in andesite, in particular.andesites, porphyries, syenite, also in cryst. slates.	do
ial- ery d.	As orthoclase.	In grains and large crystals I.O. and microlites II O When twin'd upon both the albite and pericline type a lattice structure similar to microcline appears, but the bands are more distinct.	With diallage, hypersthene, olivine, also with quartz, augite, hornblende, and biotite	Hornblende, olivine, diallage, magnetite, titanic iron. Acicular microlites are very abundant and lie c or the angle O: i–I, and brown plates (ferric oxide or brookite?) which have their long axis at right angles to the micro lites, or innumerable minute colorless or greenish grains (epidote?)	As orthoclase. Often into epidote and muscovite.	Primary, essential, in norite, gabbro, dolerites, especially also in dacite, basalts, diorite.	do
o	do	do	With hornblende, augite, biotite, diallage, hypersthene	do but no microlites and scales.	do	Primary essential in eruptives, diorite, gabbro, andesites.	do
s lab- rador- e.	Colorless, clear, as labradorite.	As labradorite.	With labradorite, augite, hypersthenite, olivine.	As oligoclase.	Usually unaltered, as the other plagioclase species.	Rather rare, primary essential in eruptives. In basaltic rocks and augite andesites, gabbro and norite. In crystalline slates, amphibolites, gneiss.	

Distinctions between the various plagioclase species.

The species lettered b–e are, as is well known, isomorphous mixtures of the two terminal members of the series—albite (ab) and anorthite (an). In physical and optical, as well as chemical characters, there are perfect transitions, and oligoclase, andesite, labradorite and bytownite are simply named members of the series.

As shown by Schuster's investigations, it is possible to distinguish the plagioclase species by determining the direction of extinction in cleavage planes parallel to O and i–ī.

The above given data of extinction refer to the customary position of the examined plagioclase, (the upper O surface inclines from left to right, as well as to the front,) and always to the obtuse angle O. i–ī, i. e. the surface ī–i lying to the right. The + sign in the case of cleavage plates ‖ O indicates that the direction of extinction is inclined to the obtuse angle O : i–ī in the direction of the right prismatic angle; in cleavage plates ‖ i–ī that it is inclined as i–ī with i–ī the — sign in both cases indicates the opposite direction.

C. *Aggregates.*

Aggregates are never dark between crossed Nicols because the numerous minute crystals are irregularly distributed. If the aggregate has a radial fibrous structure a fixed interferance figure may appear. Very often such aggregates may only he determined by chemical means.

1. *Serpentine* ($Mg_3 Si_2 H_2 O_8$ + aq.) Specif. gr. 2.5–2.7. Green, yellow or brown, to black. Characterized by the mesh structure resulting from decay of olivine. In other cases the substance consists of large plates which may be regularly arranged at right angles to each other. It occurs as an independent rock mass or a decomposition product or pseudomorph after olivine.

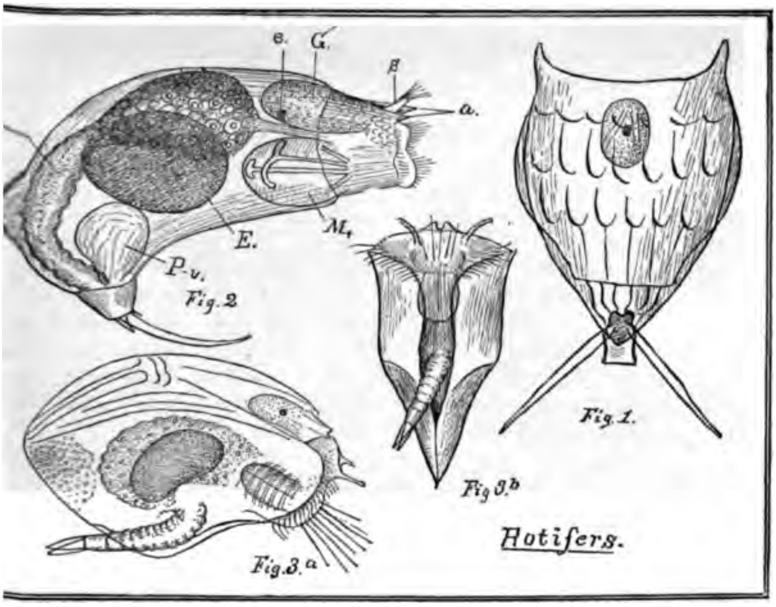
2. *Viridite.* Decomposition products of augites and hornblendes as well as garnet and biotite. (Delessite, chlorophaite, etc)

3. *Basite.* Decomposition product of pyroxene, very similar to serpentine.

4. *Chalcedony.* A secondary mineral except in quartz sphærulites.

5. *Zeolites.* Include natrolite, scolezite, stilbite, desmite, and chabasite.

6. *Carbonates.* Aragonite. Decomposing with effervescence in H Cl. Easily distinguished from calcite by crystal form.



Explanation of Figures.

Fig. 1. Distyla ohioensis, *sp. n.* (p. 54.)

Fig. 2. Diurella tigris, *Ehr.* (p. 49.) *M,* maxtax, *E,* egg, *G.* ganglion, s, sensory tube, *a,* spines of lorica, *I,* intestine, *Pv.* Pulsating vessel, *e,* eye.

Fig. 3a. Plœsoma lenticulare, *sp. n.*, side view.

Fig. 3b. do do. ventral view.

ERRATA.

Page 7, *line* 1, *instead of* preceding, *read* proceeding.
do 8, do 4. do do anteriorally, *read* anteriorly.
do 15, *Plate* I, *Fig.* 2. *instead of L. read f.*
do 48, *line* 21, *instead of* ampuliformis *read* ampulliformis.
do 59, do 12, do do Plate 1, Fig. III *read* Plate III, Fig. 1.
do 60, do 27, do do Asplanchnæa do Asplanchna.
do 61, do 33, do do ampuliformis do ampulliformis.
do 133, do 6, *et seq.* i–ĭ *read* i–i′.
do 135, do Under monoelinic, *instead of* i–ī and i–ĭ, *read* i–i′ in each case.
Table *VIII*, Apatite, instead of I,1 *read* I.1.
do *IX*, Olivine do do I=119° 2′ *read* I=130° 2′.
do *XI*, Hypersthene, under cleavage, *instead of* conchoidal fracture i–ĭ, *read* i–ī.
Table *XVII*. *Instead of* Tricilnic, *read* Triclinic.
do *XVIII*. Anorthite; cleavage, *instead of* i–ī *read* i–ĭ.

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The Natural History Department

OF

DENISON UNIVERSITY.

The work in Natural History is distributed as follows:

1. In *Biology*. The preparation assumed in such as is usually afforded in high and preparatory schools, viz: An elementary term in Human Physiology and Hygene and some preparatory work in Botany. In the Sophomore year the winter term is devoted to Comparative and Human Anatomy and Physiology. The genesis of organs and comparative (vertebrate) morphology is discussed as far as time permits. The hygenic applications of physiology are briefly presented but the physiology of the nervous system and comparative Psychology are relegated to the elective term of the Junior year. An amount of time equivalent to an hour per week is devoted to dissection and other laboratory practice.

In the following term elementary Botany is studied. The time is largely occupied with the study of phenogams and higher cryptogams. Field-work and plant-analysis supplemented by some laboratory practice in structural Botany accompany the use of the text book.

During the Junior year one term is given to Structural Botany and the study of the lower groups, including Algæ and Fungi. A part of the term is occupied with Plant Physiology. Three-fifths the time is devoted to the laboratory work. The class construct simple apparatus and conduct independently experiments in physiology.

A term in Zoology follows, and is occupied chiefly with the study of invertebrates. Begining with the cell and monocellular organism, types of each class are studied in the laboratory. In this way the developement of the vertebrate type is traced. The proportion of time devoted to lecture and laboratory work is as in the previous term.

An elective term in Zoology affords opportunity for work in Histology and special study in particular lines. It is intended to confine study very largely to the vertebrate type and an exhaustive study of one organism or system is advised. The work is supplemented by a short course in comparative psychology on the basis of Wundt and Lotze.

Geology and Mineralogy.

In the spring term of the Sophomore year opportunity is offered scientific students to study mineralogy. The work is largely confined to the laboratory, and embraces blow-pipe analysis and the elements of crystallography. Some attention is given to economic mineralogy but assaying, etc., are considered to belong with the chemical department.

The Seniors study Dynamical and Historical Geology in the fall term using Le Conte's text book, supplemented by lectures on the simpler facts of structural Geology and extended tours to interesting localities.

In the winter term a course in Applied and General Geology varies with the exigenciés arising. The course this year embraces the study of lithology, and the application of geology to the arts. Stratified rocks are studied with reference their macroscopic peculiarities and economic application. Metamorphic and igneous species are then studied by means of thin sections and the polarizing miscroscope. At other times paleontology is substituted.

OUTFIT AND APPARATUS.

For Botany an herbarium (to which additions have been received from Minnesota during the past year and a large collection is promised by Mr. Foerste) affords the needed illustrative material. A good set of compound microscopes with cameras, dissecting apparatus, staining and other reagents have quite recently been secured. Aquaria and a collection of conservatory plants will soon be provided, while the apparatus needed in vegetable physiology will be constructed by the students.

The Zoological laboratory is supplied with approved microtomes, and hardening, staining and conservative fluids, injecting apparatus, etc We at present lack the costly apparatus for physiological investigation and records but it is hoped that this need may be soon supplied. Physiology is illustrated by prepared skeletons, casts, microscopic slides, etc., but much more is needed. The instructor will soon have ready a large suite of specimens illustrating comparative anatomy. The cabinet, though small, is rapidly augmenting, having more than doubled in effectiveness during the year past.

In Geology charts and illustrative material are of a good quality, but requiring many additions. The supply of type minerals and rocks has been materially increased. A lithological lathe and polarizing microscope of modern construction as well as over one hundred typical rock sections have been secured. Apparatus for applying micro-chemical tests is also supplied.

Although much has been done, there are many wants unsupplied. The room is much too limited and two additional appartments could be at once employed. The cabinets in all departments need great additions to make them adequate for purposes of illustration. To this end friends are earnestly solicited to send to the professor in charge specimens of any and all natural objects from various parts of the state. No animal or stone is so common (if perfect in its way) as to be useless. Contributions in money will be carefully expended to the same end in securing exotic specimens.

Directory of Colleges of Ohio, Etc.

ALPHABETICALLY ARRANGED.

ADELBERT COLLEGE, OF WESTERN RESERVE UVIVERSITY.

CLEVELAND, OHIO.

PRES. REV. CARROLL CUTLER, D. D.

Open to both sexes on equal terms.

Adjuncts: Medical Department, G. C. E. Weber, LL. D., **Dean; Western Reserve** Academy, Principal, N. B. Hobart, A. M., **Hudson, O. Green Spring** Academy, Principals, P. E. Laner, A. B., **and M. J. Hole, Green S**prings, O.

Two courses are provided in the collegiate department, leading to the degrees of Bachelor of Arts and of Letters respectively, and special courses with certificates, libraries contain about 12,000 volumes. The departments of Chemistry and Physics are well supplied with apparatus. The observatory is equipped with a five-inch equatorial and a three-inch meridian circle. The museum contains well-selected and increasing geological and other cabinets. Next year begins September 9th, 1886.

BUCHTEL COLLEGE.

AKRON, OHIO.

PRES. REV. ORELLO CONE, D. D.

Three courses of study, these are:—The Classical, Philosophical and Scientific course, leading to the degrees B. A., Ph. B. and B. S., respectively. All studies are elective after the first term of Sophomore year. The faculty consists of eighteen professors and instructors. The college was founded by the Ohio Universalist Convention in 1870. Its outfit embraces an astronomical observatory fully equipped with instruments and improved physical and chemical apparatus and a cabinet of Natural History. Those designing to teach receive the benefit of regular instruction in methods of teaching. Year begins on the first Tuesday in September.

DENISON UNIVERSITY.

GRANVILLE, OHIO.

PRES. ALFRED OWEN, D. D.

Denison University comprises both a collegiate and a preparatory department. In the college department are three courses leading to the following degrees, A. B., B. Ph., B. S., with preparatory courses corresponding.

The college has eleven Professors and instructors, well equipped Chemical, Physical and Biological laboratories and a large and excellent library. The productive endowment exceeds $300,000. Instruction is thorough and expenses low. Those who cannot take a full course are permitted to take special studies when they can do so with profit to themselves and without injury to others. School year from Sept. 9, 1885, to June 24, 1886. The next school year commences Sept. 6, 1886.

HIRAM COLLEGE.

HIRAM, PORTAGE CO., OHIO.

PRES. GEO. H. LAUGHLIN, A. M.

Four courses, comparing favorably with best colleges in Ohio, viz:—Classical, Philosophical, Scientific, and Biblical. Faculty of twelve competent instructors. Total number of students 205, of whom 99 are ladies. Ample provision for instruction in music and drawing, as well as in the elementary branches. The outfit in science includes valuable collections of Western ores and fossils from Dr. F. V. Hayden and contributions from the Smithsonian Institute. Valuable additions have been made to the philosophical apparatus of the college. Tuition and board at reasonable rates. First term opened Sept. 1, 1885, and the year closes Thursday, June 17, 1886.

OHIO STATE UNIVERSITY.

COLUMBUS, O.

PRESIDENT, W. H. SCOTT.

The University has twenty-five professors and instructors. It offers eight courses of study leading to degrees as follows:—B. A., B. Ph., B. Sc., C. E., Mining Eng., Mech. Eng., B. Ag., and V. S.; preparatory course, a short course of two years in agriculture, and a course in pharmacy.

It possessess eleven well-equipped laboratories,—Physical, mechanical, chemical, metallurgical, agricultural-chemical, botanical, and physiological, and the most extensive and valuable museum of Ohio geology.

Its land, buildings, equipment and endowment are worth more than one million, one hundred thousand dollars.

OHIO UNIVERSITY.

ATHENS, OHIO.

CHAS. W. SUPER, PRESIDENT.

Classical, Philosophical, Preparatory and Normal departments. Instruction is chiefly given by the regular professors who are more or less specialists in their departments. Much new apparatus has recently been purchased to illustrate Physics and Chemistry. A chemical laboratory with gas and water has been provided. Young ladies are admitted to all departments upon the same terms with young men. One student from each county is entitled to a free scholarship, the conferring of which is in the hands of the county auditor and commissioners. Fall term begins Sept. 7, 1886, spring term begins Mar. 30, 1886.

OHIO WESLEYAN UNIVERSITY.

DELAWARE, OHIO.

C. H. PAYNE, D. D., LL. D., PRES.

Offers to both sexes, at surprisingly small expense, unsurpassed advantages for a full collegiate course or for special studies. Collegiate, Preparatory, Normal, Commercial, and Art Departments. First-class Conservatory of Music. Elegant home for ladies, with teachers. Necessary expenses per term $50 or less. As at present constituted, the museum embraces four distinct cabinets:

1. William Wood Cabinet of Casts of Fossils. 2. Mann Cabinet of Palæontology. 3. Prescott Cabinet of Biology, and 4. Merrick-Trimble Cabinet of Mineralogy.

The library embraces 13,786 volumes.

The study of the Bible is persued in some form by every student during his entire course.

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BROOKE CO., W. VA.

PRES. W. K. PENDLETON, LL. D.

Four courses, leading to appropriate degrees, viz:—Classical, Scientific, Ministerial and Ladies' courses: also special *Professional Courses* in Engineering, Practical Physics and Chemistry, with ample training in field-work and laboratory with use of instruments and apparatus. Now in 45th session. Alumni number 640. Expenses are reduced to a minimum, and every facility for economy in time and money is afforded. All classes open to both sexes. Year begins the last Monday of September, closing the third Thursday of June. For catalogueaddress Prof. W. H. Woolery.

LABORATORY SUPPLIES.

In order to facilitate the study of Natural History in Ohio the department has arranged to furnish such laboratory supplies as may be accessable in convenient sets adapted to college or high school or individual use. The business will be conducted by Mr. C. J. Herrick, while the preparation of the material will be under the immediate direction of the department.

No. 1. *Lithological suite* consisting of 25 hand-samples of type rocks with accompanying thin sections and a lithological microscope manufactured expressly for the department, also apparatus for making thin sections by hand, - - - - - $75 00

Lithological lathe (additional) - - - - - - 50 00

No. 2. *Suite of stratified rocks*, 25 samples, accompanied by sections of the most important building stones and fossils typical of each rock and one of Bausch & Lombs' model microscepes, complete, - - - - - - - - - - $65 00

Sections of rocks or fossils will be made on application at a low rate. Other laboratory supplies will be secured and kept on hand as opportunity affords. Address C. J. Herrick, Granville, O.

THE TWENTIETH YEAR!

THE AMERICAN NATURALIST:

A Popular Illustrated Magazine of Natural History and Travel.

ANNOUNCEMENT FOR 1886. VOLUME XX.

This journal of popular Natural Science is published by Messrs. **McCalla & Stavely**, Philadelphia, Pa., under the editorial management of **Dr. A. S. Packard**, and Prof. E. D. Cope, with the assistance of **eminent men of science. The** typographical dress and illustrations which have heretofore **given character to this** magazine will be sustained, and it will be of a thoroughly **popular nature, so as to** interest the general reader as well as the young naturalist. **It will continue to be** a journal of science-education and for the use of science teachers.

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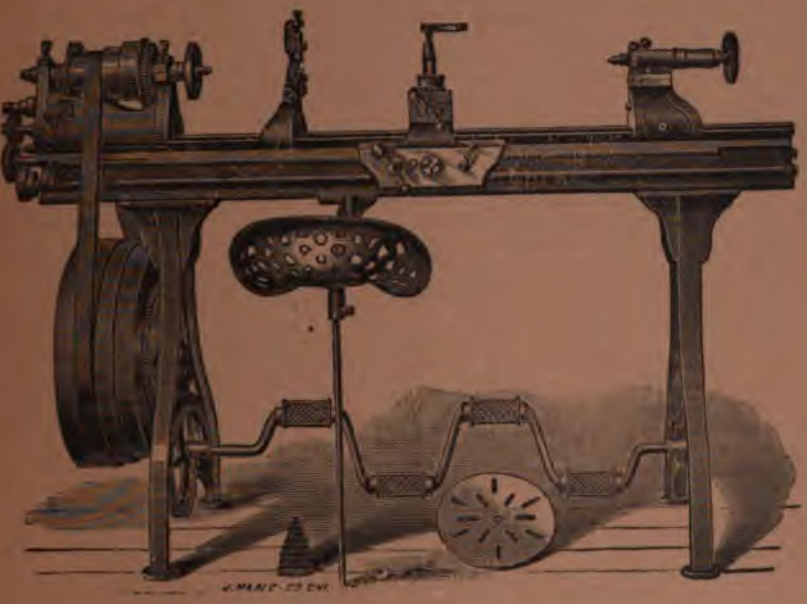

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EDITED BY

C. L. HERRICK, DEP'T OF GEOL. AND NAT. HISTORY,

AND

A. D. COLE, DEPARTMENT OF CHEMISTRY AND PHYSICS.

VOL. II, PARTS 1 AND 2.

GRANVILLE, OHIO, MAY, 1887.

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OF THE

SCIENTIFIC LABORATORIES

OF

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EDITED BY

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EDITORIAL STATEMENT.

We note with pleasure the growing interest in the work represented by this publication and the greatly increased facilities now afforded for advanced work. The present volume, although the work of more hands than that of last year, does not adequately indicate the scope which the publication is expected to cover, because a disproportionate amount of space has been given to geological discussions, the results of which it is hoped to immediately employ. Several articles again crowded out, as well as the promised instalments of continued papers, will appear in the next issue The department of Chemistry and Physics may be expected to contribute its full quota to the interest of the publication.

We need hardly remind the professional naturalist that other considerations are subordinated to the educational, and the papers are strictly, as they profess to be, outgrowths of class work and laboratory exercise. If, notwithstanding, results of a certain degree of interest as contributions to science develop, it will not be regretted by us. It ought not to be necessary to say that the material is in each case original, and collected, as well as elaborated, by those to whom it is accredited.

The uniform kindness of the learned societies from which exchanges have been solicited, calls for grateful recognition on our part. A full acknowledgement will be found in the next issue.

To kind friends who have contributed apparatus and specimens we can only speak general indebtedness. A freezing microtome manufactured and donated by Dr. Jacobs, of Newark, should be appreciatively mentioned, as also a valuable collection of eggs presented by Mr. G. D. Pearce. Finally, it should be said that the means for sustaining this publication have been secured solely by voluntary contribution, almost the entire amount being donated by Hon. E. J. Barney and Hon. J. B. Thresher, of Dayton, and another person too immediately interested to care to allow his name to appear. The results of the laboratory class on lake Superior, during the last summer, were so satisfactory that it is hoped to repeat the experiment on a larger scale during the summer of 1888. The editors will be glad to correspond with teachers and others desiring such opportunities as would be afforded by laboratory work at a station located upon the Gulf of Mexico. The work will depend somewhat on the desires of those participating, but will consist chiefly in lectures on biology, chemistry, physics, and geology, and laboratory study in these branches, as well as detailed investigation of the peculiar fauna of the Gulf. The co-operation of eminent southern naturalists is assured, and the imperfectly known crystalline rocks of the South will afford a fine field for the lithologist, as the proposed scheme involves a short tour in the mountains of Alabama. The facilities of the college laboratories will be placed at the disposal of the workers so far as may be practicable and all obtainable aids will be secured.

A Sketch of the Geological

HISTORY OF LICKING COUNTY,

Accompanying an Illustrated Catalogue of Carboniferous Fossils from Flint Ridge, Ohio.

Every acre of our earth's surface is marked with tracery which, if patiently studied and correctly interpreted, will supply pages in the history of creation. The mind which has ceased to be interested by the record thus preserved or which inclines to ridicule the youthful enthusiasm which sees in all natural phenomena manifestations of Divine intelligence, must be far forward in its differentiation (or rather indifferent-ization) toward the *Nirvana* of blase' modern scientists.

We believe that there is vast gain every way in supplementing the natural curiosity which furnishes the earliest incentive to investigation by maturer faith in immanent Divinity in nature. Still more useful is it if one feels that the problems afforded by the earthy records are God's gifts to us with the intent that we should learn to know his will concerning the earth as well as ourselves.

This paper is intended to outline briefly those facts in the geological history which lie easily within the reach of any one living in this county, and to afford the means of studying intelligently the portion of the geological column lying exposed in this part of Ohio. In as much, however, as the column is an integer, the investigation of one part is of importance in the study of the rest.

Far too little has as yet been done in the careful and systematic study of limited fields. We need in geology more than elaborate generalizations on insufficient data, carefully elaborated pictures of limited areas and the succession of life traceable in closely related strata. We believe it possible to become almost as familiar with the fauna and flora of Licking county, for instance, during the time when coal deposits were forming as we are with its present animals and plants. The question whether the earth has been repeopled at the opening of each era, as claimed by some, or gradually reached its present condition by progressive development and continuous differentiation, is most likely to be settled by such detailed study of superposed strata. The work represented by the notes here given has been the recreation of spare moments during less than a year, but has been sufficient to indicate an almost exhaustless mine of interesting information. It is hoped that the study may be pursued much further. The accumulation of material has been greatly facilitated by the co-operation of the class in lithology of 1886, some members of which have continued to assist in the necessary collecting and field-work. Mr. Foerste, of '87, has also rendered efficient aid in collecting and otherwise.

In as much as the study was carried on independently of the published reports it is gratifying to observe the substantial accord of our results with those of the Geological Survey, so far as the latter extend. The examination was restricted to a band some miles in width, extending from Alexandria to Brownsville, with the view of perfecting a geological section across the line of contact between the coal measures and the sub-carboniferous formations, which alone are here represented. Our plan has been to study the various quarries and natural exposures, gathering such information as may be furnished by fossils or stratigraphy, then proceeding to parallelize as far as possible the strata which are recognizable. It is surprising how many hints a barren looking heap of rock may often furnish. The dip of strata is often only obtainable by the use of a transit as it varies little from the horizontal. As we pass from horizon to horizon the imagination sees broad sandy shoals, marked by ripples, and here and there exposing to view bivalves of unfamiliar form, or detached valves of brachiopods. Again a shallow lagoon, with a muddy bottom supporting a luxuriant vegetation of Spirophyton sea-weeds, whose broad leaves floated about like the pond-weeds of to-day. Among these darted the trilobites, springing backward by a quick stroke of the tail, or lazily floating near the surface, or crawling along the under surfaces of their leafy retreats. In clearer spots the sea-lily spread its graceful but direful petals while an occasional horny shielded fish flashed by in pursuit of slow-swimming gasteropods. Here one reads proof of a stormy promontory, where the waves ravened pitilessly about the abutting cliffs, and scattered the eroded material in bars and banks within sheltering coves, or distributed it by currents more equally over a wide area. Such was the condition of Granville and the adjacent townships before it was raised forever beyond the creative touch of the ocean. The Waverly group of rocks is the result of the quiet but constant efforts of our most modern sea. Farther east, however, the sea still continued, but cut off from direct communication with the western ocean and only now and then keeping up the union at the south. The townships of Madison and Hopewell were covered by shallow lagoons of salt water. It was now a period of quiet. The gradual formation of a ridge of considerable width, along the axis, extending from Cincinnati to Toedo, had cut off the "sou-westers," which had stunted vegetation, land along the borders of the steaming lagoons a dense forest of ferns and succulent vegetation of unfamiliar kinds sprang up. The lepidodendrids, whose trunks had occasionally been preserved in the sand-bars of the Waverly sea, gave place to a more dense growth, which literally buried itself under its own profusion and the decaying boughs were soon submerged by the variable, though shallow waters. There were, however, constantly recurring periods when the ocean asserted its ascendency; local or general depressions were followed by invasions of deep arms of the sea, which eroded the distant granite or nearer sand hills and covered all evidences of forest luxuriance with sand. The animals which swarmed in the shallow lagoons were such as are found everywhere in the coal measures and the accompanying plates illustrate the most important species.

The above history is recorded in alternating layers of shale, coal, and white sandstone. In the following diagram the sequence of strata is illustrated, while the sections of Fig. 2 show the chief observed exposures and their relations, as further indicated upon the geological map.

(The section represented in Figure 1, is, in general, east and west, but there is also introduced a partial section from Madison township, which is nearly north and south, exhibiting a greater dip, probably of a local nature, as above indicated. The vertical scale is greatly exaggerated—50 feet vertical, equalling one mile horizontal.)

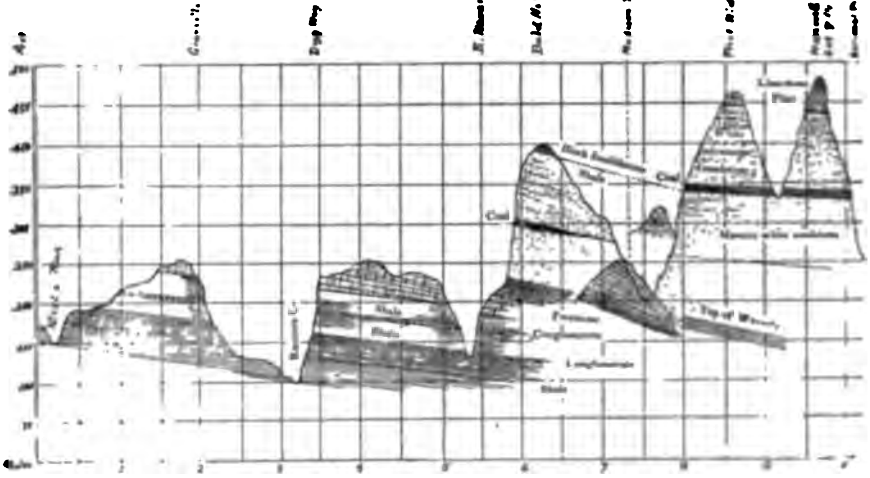

Fig. 1. SECTION FROM MOOT'S RUN TO FLINT RIDGE, LICKING CO., OHIO.

There is nothing to indicate any great disturbance in position in the strata since their deposition. Although there is no obvious unconformity between any of the strata exposed, yet the fact that so many of them are shore deposits and the fact that farther south and east bands of limestone are interpolated, indicates that here and there there must have been intervals of considerable duration when the process of accumulation was interrupted and the days ran round unrecorded. Any attempt to estimate the time represented must include ample allowance for such breaks in the continuity of the series. Within the limits of our study about [illegible] feet in vertical thickness can be assumed, of which 2[illegible] feet consists of the coal measure rocks, and the remainder of shales and freestones of subcarboniferous age. It is probable that 1[illegible] feet should be added below the rocks exposed in this part of the county to reach the dividing line between the Devonian and carboniferous. We have then some 5[illegible] feet of material, representing at least, say 5[illegible] years, without allowance for the intervals.

M[illegible] of the material, undoubtedly, accumulated much more rapidly [illegible] while the shales and coals no doubt represent [illegible] Highly carbonated waters and [illegible] erosion, while the profusion of vegeta[illegible] greatly increased the deposit of organic matter.

Altogether, it would seem that modern measures as applied to calculations in the Paleozoic, are likely to be too long rather than too short. Here the question naturally arises, what is the source of all the material thus accumulated, especially the quartz. Most of the white sandstones of the coal measures are highly micaceous and in places the loose sandstone has a schistose character, due to the presence of large amounts of light colored mica. Such deposits can be most readily explained by supposing them more or less directly derived from granite rocks, which were first kaolinized, the aluminous or fedspathic ingredients being separated and floated to a distance, there producing the shales, while the sand is accumulated near the shore line. The mica is partly separated, but is always found in connection with arenaceous deposits. But how is it that such large deposits of sand are found at so great a distance from granitic ranges ? To this it might be suggested that many spurs of the Archean continent had remained even near this area and that the material was thus derived directly. Such spurs would, however, be very likely to leave other evidences of their existence. It might be, on the other hand, that during the preceding (Devonian) age, sandstones had been accumulated, which now fell a prey to encroaching and receding seas. But in such a case we might hope to find fragments of the fossils of the Devonian among carboniferous deposits or in other ways receive information of the appropriation, much as the old parchments used for church missials have been forced to reveal the more ancient heathen lore inscribed beneath. Aside from the negative evidence hinted at, we have the fact that there are here and there conglomerates containing quartz-fragments which must in all probability, have been derived from veins such as are found in igneous rocks. A third explanation is that the highlands on the east and north really supplied the materials and that they were floated and rolled to their present positions by tidal and wave action. This theory receives incidental confirmation in several ways. We find the heavier materials collected more considerably to the east, even in as narrow an area as our own. Bands of Waverly rock, which at Granville consist of freestone, become conglomeritic east of Newark. Northeast of Clay Lick there seems to have been a promontory or low spit during the early part of the Waverly epoch. Here accumulated quantities of sand and conglomerate, while to the south and west layers of shale and freestone were formed at the same horizon. Then, as now, the dip was southwest at this point, and in the more protected reach of shore to the west, there gathered at intervals great floating beds or tangles of sea-weeds. Currents setting from the northeast, bearing freight of sand and gravel, would naturally deposit all but the lighter in making this point, and in the slower eddies beyond drop the clays we really find.

Now it remains to notice that there was evidently a considerable interval between the fossiliferous beds of the upper Waverly and the fossil bearing shales of the coal measures—a far greater interval than is represented by the 170–180 feet intervening. An interval of 100 feet between the shale at Flint Ridge and the silicious limestone seems to have produced no marked change in fauna, many identical species being found, while very few forms pass from the Waverly into the coal measures. This might be partially explained by the changed conditions, but that this is insufficient is indicated by the fact that Waverly freestones contain many species identical with limestones of the same horizon (Spergen Hill) in Indiana. However, it may be in part explained by supposing that the waters during the Waverly epoch were connected with the sea at the west, while during the coal measures period the sea was part of a southeastern basin, which in the meantime had become independent. Nevertheless, we have evidence of a period left unrepresented in Licking county, but which was employed farther south in the formation of sub-carboniferous limestones (Maxville.)

In order to determine the exact relation between the strata mentioned it will be necessary to carefully study and compare all the remains preserved, as well as to carry stratigraphical research beyond the limits assigned. We will examine, therefore, first of all the fossils found in a thin layer of black shale immediately overlying the coal at Flint Ridge and lying about 100 feet below the summit of the ridge. This stratum appears upon the top of Bald Hill, near Newark, with identical fossils and lithological character. It is here not supported by coal, but lies 100 feet above the lowest coal horizon in the county (about 73 feet only above the Waverly). This shale also appears toward Brownsville, wherever its horizon is reached. This is undoubtedly coal measure rock and its fossils are those found in the coal measures of West Virginia, Illinois, Missouri, and the far West. After enumerating these, comparisons may be instituted with the Waverly and sub-carboniferous limestone as well as the silicious limestone above. This narrow band of shale is one of the most highly fossiliferous strata known, though the number of species is not relatively so great.

Should there be found errors of identification, as would be natural where it has frequently been impossible to obtain reliable examples of related forms, and in spite of obvious incompleteness, it is hoped that, in as much as most of the forms described are figured, this catalogue may serve a good purpose in several ways.

The Surface Geology of the southeastern part of Licking county, does not present any very striking points, but it may be interesting to notice a few of the salient features. The drainage is toward the southeast, the tributaries of the Licking river, constituting almost the only streams, except in Bowling Green township. The only large body of water is the reservoir in Union and Licking townships.

Granville township furnishes numerous exposures of the Waverly rock, which here may be separated into an upper massive portion furnishing available freestone for foundations and construction below the water table and for coarse masonry, and the lowest shaly portion which is here and there interrupted by beds of freestone. The quarries are all in the hill tops and may be found in many parts of the township, everywhere, in fact, where the elevation is great enough. But few are worked more than needed for local consumption, but in the vicinity of Granville, especially in the hills lying north of the village, are several which are considerably developed. The best exposure in the township is midway between Granville and Newark and is formed by the erosion of Raccoon creek. The section at this place is a typical one and exposes all rocks found in the township, except a few feet above. About 150 feet is therefore the approximate vertical measure for the township. The upper courses are in places very fossiliferous, Crenipecten Winchelli being a characteristic fossil. Below it is a layer of shale characterized by the plant Spirophyton, and below this an 18-inch band of conglomerate. A few feet below the conglomerate is a dark shale, affording many lamellibranchs, Allorisma hannibalensis being abundant. The free-stone below is apt to be full of a species of Camerophoria and many other fossils. The lower shales are usually barren of other fossils than the stems of fucoids. At Spring Valley, a beautiful dell a half mile southwest of Granville, a good exposure of the shale may be seen which is, however, much surpassed at Moot's Run, nearer to Alexandria. Union township lies almost wholly below the free stone, though several exposures of the shale may be found along the streams. This shale is in many places highly concretionary, the nodules often containing plant or animal remains. At Moot's run, some interesting Producti have been found imbedded in these concretions. Northeast of Granville is a very rough section of the county and here the conglomerate is more highly developed than elsewhere, and is often highly fossiliferous, Chonetes illinoisensis, Spirifer carteri, and two other species, as well as large specimens of Hemipronites being the characteristic fossils. The highest hills in this vicinity are perhaps [illegible] feet above the altitude of the conglomerate, at the "dug way," and may be near the line of juncture with the coal-measure sandstone or, indeed, may contain a few feet of that rock, though only surface fragments of such a rock have been seen. The thickness of the conglomerate or coarse Waverly sandstone is estimated at twenty feet and graduates insensibly into the olive free-stone, as well shown a half mile northeast of the "dug way," half way from Granville to Newark. The free-stone extends in these hills to some 120 feet above their bases, (or perhaps 60-80 feet above the 18-inch layer of conglomerate, this being a mere estimate). The dip is here very slight, probably southeast.

Hebron Hill, south of Granville, is 106 feet above the B. & O. track, south of it. South of Newark, along the right bank of South Fork of Licking, are many exposures of the Waverly rock. The abutment of the bridge crossing this stream, west of Mechanicsburg, is 170 feet lower than the top of Hebron Hill and about 60 feet below the B. & O. track, as indicated. The hills east of the bridge rise, 180 feet and do not reach the coal-measure sandstone. The village of Mechanicsburg is 150 feet above the abutments, but a few rods east, at the Licking township line, are hills over 200 feet high, with thirty to forty feet of the characteristic white sandstone and conglomerate. It is here massive and might be quarried with ease. A few rods northeast is a high hill, 300 feet above the bridge, where there seemed to be about 115 feet of coal-measure rock, part of which is a ferruginous shale, and extends far above the horizon of the Bald Hill coal. Indeed, some indications of its presence could be detected. The summit of this hill is some 60 feet higher than the horizon of Bald Hill coal and another hill east of Bald Hill rises to a considerably greater height, though not to the horizon of the Flint Ridge shale, as does Bald Hill, 100 feet above the coal. The reservoir lies in a depressed region in Union and Licking townships, but is bounded on the east by low hills. A trip through this region revealed the presence of Waverly shales and freestone, with characteristic fossils. A mile eastward, 45 feet above the T. & O. C. R. R. track at the reservoir, by combining various exposures a thickness for the Waverly of over 100 feet at least can be made out. Thornville is about 180 feet higher than the railroad, and the Waverly shales west of Amsterdam are ten or twenty feet higher. A range of hills half a mile to the south of the National Road, rise to 280 feet and expose at least 85 feet of coal-measure sandstone and conglomerate, here of a white color and full of Lepidodendron stems and other plants. The base of the sandstone is marked by a line of springs. It is not now possible to compare these elevations with those farther north, but evidently the relations are precisely the same. Although a sub-carboniferous limestone is marked on the map published by the Ohio Geological Survey, no indications of its existence were seen in Licking county. On the other hand, the Waverly seems to extend to the base of the coal-measures exactly as elsewhere.

Passing east from Newark many exposures of the Waverly are found along Licking river, but the most characteristic exposure is in a large quarry (the largest in the country), in the southeastern corner of Newark township. It is possible to trace the whole section from Licking river to the top of Bald Hill, in the southwest corner of Madison. The results of our study are embodied in the section accompanying.

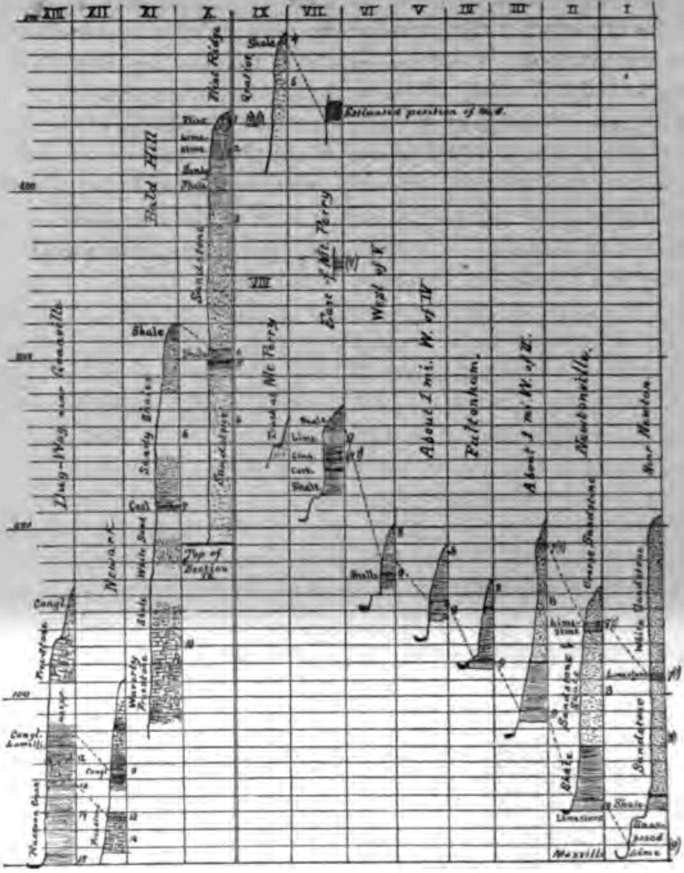

Fig. 2. GROUPED SECTIONS FROM GRANVILLE TO NEWTON.

Franklin and Hopewell townships are very rough and are intersected in every direction by valleys. Flint Ridge, the highest portion of the county, furnishes the best continuous section of the coal-measures. In the southeastern part of Madison township are several hills which reach within 200 feet of the top of Flint Ridge, *i. e.*, to beyond the base of the coal-measures sandstone. In the northeastern part of Franklin township are several hills exposing various parts of the coal-measure series which seems to dip rather strongly to the south. The coal at Flint Ridge occupies a small local basin and cannot be expected to prove continuous. It seems to lie some 160 feet above the Waverly. The highest hill in the county, so far seen, lies in Hopewell, a mile or more south of this mine, and its summit is 135 feet above the coal. The upper 30 fect or more is composed of the flinty limestone which caps the ridge. This limestone contains many impressions of foramifera (Fusulina cylindrica), and but few fossils, among which are Chonetes mesoloba, Productus longispinus, Pernopecten n. sp., Euomphalus sp., Productus muricatus, P. nebrascensis, and bryozoans. This hill is 250 feet above the National Road, directly south. This road is mended with the carboniferous shale of the horizon of the Flint Ridge coal. Near Brownsville the sub-carboniferous limestone is said to appear, but we have not been able to find it, and it seems impossible that so low a horizon could be reached.

It remains to take a hasty view of the region about Clay Lick Station, in Hanover township. Here in the middle of Hanover is a great development of the conglomeratic phase of the Waverly. One half mile east of Clay Lick there is a nearly continuous exposure of about 100 feet of alternating conglomerate and coarse sandstone of prevailingly red color. West of Clay Lick there is a considerable dip to the west or southwest. The dip is about seven feet to the hundred. At a distance of a mile south or northwest the exposure gives a dip of about 3.6 feet in the hundred to the northwest. These may be simply local flextures. It is altogether probable that a spit or bar extended into the sea northeast of Clay Lick and there great quantities of sand and gravel were accumulated, while the clayey deposits to the south and west were longer under the sea and sank somewhat under the weight of the massive deposits south of them. In the creek bed at the last mentioned exposure, a mile south of Clay Lick, is nearly a hundred feet of continuously exposed Waverly, showing none of the conglomeratic character found east of Clay Lick.

In order to define as nearly as possible the relations between the formations in Licking and adjoining counties, a hasty excursion was made into Muskingum county, with the results compendiously exhibited in the sections of Fig. 2. The barometic readings were interfered with by atmospheric changes in passing from Mt. Perry to Brownsville, so that the connection is not complete, but it is believed that the relations are relatively correct. Near Newton is a good exposure of over 200 feet, which is shown at No. I. The Maxville limestone is near the water and continues near the surface of the stream nearly to Mt.

Perry. The dip from Mt. Perry to Newton appears to be not less than 250 feet, with no noticeable change in the relative thickness of the exposed strata. The whole distance southeast represented by the grouped sections, is about 30 miles. The dip southeast accomplished in this distance is roughly estimated at from 300 to 350 feet, or something over ten feet to the mile; but the dip is much more abrupt after passing about six to eight miles east of Granville. It would seem from observations so far obtained that there is every where a rather abrupt decline along a line a short but variable distance from the edge of the coal field, so that the sub-carboniferous with a portion of the coal-measures extends outward in the form of a flat rim to the more concave central basin. In some places this line is almost of the nature of a fault and causes some obscurity. This line crosses the Licking river a mile or so east of Clay Lick.

In the next paper we shall be able to make more detailed comparisons of the faunæ represented. Enough is now known to assure us that many species have continued from the beginning to the end of this period. In other cases the coal-measures contain forms which might be considered the somewhat modified descendants of Waverly species. Nevertheless there are many, perhaps a majority of forms which do not exhibit a traceable connection with the Waverly or lower horizons. How much of this disparity is to be explained by the changed conditions of life—how much by the fact that the connection was with a different sea basin, and how much these categories leave unexplained, bids fair to prove a perplexing question. Such problems as these demand careful scrutiny and, if possible, adequate treatment.

CRUSTACEA.

TRILOBITA.

Only one species of trilobite has been encountered and this is fully described in connection with the discussion of Carboniferous trilobites upon a later page of this issue.

The only other remains suggesting crustacean affinities is the curious valve or plate, figure 21, Plate I. In some respects this resembles the valve of an Ostracode crustacean, with a very thick shell.

MOLLUSCA.

CEPHALOPODA.

Genus Orthoceras.

Orthoceras cribrosum, Geinitz. (?)

(Plate V, Fig. 2.)

There is but one species of Orthoceras at all abundant at Flint Ridge, and this is invariably more or less crushed. A smaller species like O. rushensis, has been doubtfully identified. An average example of our species is from three to four inches in total length, with a rather gradual expansion. About a fourth or fifth part of the shell below is without visible septa and is more rapidly expanded than the remainder, which is apparently cylindrical, having moderately concave septa, separated by intervals of about four and one-half into the width of the shell. The siphuncle is apparently nearly central (?) The shell is very thin and the epidermis apparently unornamented or granular. The removal of the epidermis reveals a nodose line near one side, the nature of which has not as yet been determined (Cf. O. duseri of Lower Silurian.)

It is by no means certain that the identification is correct. Geinitz laid stress upon the pitted nature of the shell, though his figure shows the epidermis to have been exfoliated.

Natilus sp.

(Plate II, Fig. 17.)

Fragments of what appears to be a Nautilus allied to N. forbesianus, McChesney, are not rare, but none of them indicate the shell to have been septate. Awaiting additional material these are inferred to be identical with N. decoratus of Cox, identified with the above.

GASTEROPODA.

GENUS BELLEROPHON.

Bellerophon percarinatus, Conrad.

(Plate II, Fig. 14.)

Shell subglobose; laterally expanded at the front; umbilici closed; outer lip thin at the front, thickened by callus at the sides; inner lip thickened by callus, which is sometimes in the form of a broad, prominent lobe, and that at the median line; the last volution is always marked by one strong, rugose or nodose median carina, which extends from the inner lip to the front margin; in most cases there is a more or less distinct revolving ridge at each side of the median carina, and of equal extent with it; the whole surface is also marked by strong transverse wrinkles and lines of growth, but sometimes the lateral ridges are wanting. Length and breadth equal.

This species is represented by several recognizable fragments from Flint Ridge and Bald Hill. The description is quoted for reference.

Bellerophon nodocarinatus, Hall (*fide White.*)

(Plate III, Fig. 3.)

A number of specimens of a rather large Bellerophon are in exactly the condition figured by White, in the 13th report of the Geological Survey of Indiana. The lip seems to be but slightly expanded; general form, sub-globose; dorsal surface of outer volution, with a subnodose median carina which is divided by a furrow, in which at the bottom is a slightly raised line; on either side the carina a broad, shallow sinus; proximally the volution marked by prominent distant revolving ridges and the carina disappears; the carina seems to terminate in a slight dorsal emargination of the lip.

None of our specimens preserve the aperture or umbilicus. White is inclined to believe his *B. inspeciosus* a variety of this species.

Bellerophon (*sub-cordiformis*, sp. n.)

(Plate II, Fig. 7 a, b, c.)

A fragment of a small Bellerophon may be noticed, which appears to indicate a species entirely distinct from any known to the writer. Neither the mouth nor the umbilicus is visible, but the last coil is evidently very rapidly enlarged. The outline, as viewed from behind, is cordate; the diameter in the plane of the coils nearly equal to the width; middle of outer coil carinate, lip apparently regularly expanded; surface marked by oblique, revolving, rounded ridges, springing from the median carina and passing toward the lip, between these ridges are impressed lines, containing prominences disposed at regular intervals. This peculiarity of the surface markings alone is thought characteristic. Width, over 0.4 in., height about the same. Should a name be required for this species it may be called *B. subcordiformis*. (A somewhat similar surface ornamentation is found in the otherwise very different *B. pullchellus* of Toula.)

Bellerophon Montfortianus, N. and P.

(Plate II, Fig. 1; Plate V, Fig S.)

The largest Bellerophon found at Flint Ridge agrees with this fine species. We are able to give more complete figures than hitherto obtained, many of our specimens, though crushed, being entire.

Shell proximally very small, expanding rapidly; aperture enormously expanded, sub-reniform; outer volution with a deeply impressed medial sulcus emarginating the lip distally; lip thin, with a prominent callous where covering the inner coil. The surface is ornamented by strong revolving lines, which are separated by about ten striæ and are crossed by fine concentric striæ, giving the whole a delicate textile nature. In one of the specimens figured the revolving lines do not reach the lip, but the zone with only concentric lines seems due to exfoliation. The surface is also marked by distant concentric plications which become more numerous proximally. Width of aperture, 1.24, height, .95.

Bellerophon decussatus, Fleming ??

(Plate II, Fig. 12.)

Our figure represents the dorsal surface of the outer volution, which is marked by a combination of revolving and concentric striæ of nearly equal size and number. There is also a slight median fold. It is not certain that the identification can be sustained.

Bellerophon carbonarius, Cox.

(Plate II, Fig. 20.)

This, or a closely related species is represented by only a few fragments. (Cf. also B. stramineus.)

"Shell globose, broadly rounded over the dorsum; umbilical impressions very small or closed. Aperture transversely sublunate, much wider than high, and strongly arched, but not expanding more rapidly than the uniform increase of the size of the volutions; inner lip nearly wanting or little developed; outer lip moderately thick near the umbilicus on either side, but thinner between; sinus shallow and rounded, its band obscure or scarcely visible on the costated part of the outer whorl, sometimes a little concave, or with traces, on each side, of a faintly marked ridge on the smooth part of the outer volution; surface, except on the terminal half or third of the body whorl, ornamented with about 18-25 simple, rather distinct, revolving raised lines." This species is widely distributed.

Bellerophon marcouianus, Geinitz

(Plate V, Fig. 7[illegible]

Several fragments are sufficient to [illegible]te this species, but add nothing to the meagre description given by [illegible]einitz and Meek. The shell is marked only by fine, close, u[illegible]r alternating, revolving lines and has an aperture like B. mon[illegible]s, which it approaches in size.

Bellerophon (cf. *crassus*, Meek [illegible]nd Worthen.)

(Plate V, Fig. 6.)

This Bellerophon is derived from the fl[illegible]y limestone at the summit of Flint Ridge, and hence its horizon is [illegible]oo feet higher than the shells just described. Though much smaller than B. crassus, it has much the form of that species, yet the shell appears not to have been thick. The umbilical expansions of the lip are broken, but may have partly covered the cavity. The markings are nearly obliterated, but there are indications of a mesial ridge on the dorsum. The greatest diameter is over one inch.

Polyphemopsis inornata, Meek and Worthen?

(Plate II, Fig. 15.)

Even the generic reference of this specimen must remain doubtful, as it is so largely imbedded in the rock. If a Polyphemopsis, it resembles *P. inornata* as nearly as any American species encountered. *P. melanoides* from Newtonville would appear to be too slender. Our specimen is larger than the type of P. inornata.

Macrocheilus sp?

(Plate II, Fig. 16.)

A single specimen, pretty well preserved, but unfortunately not displaying the characters of the columella, seems to indicate a species of Macrocheilus, about the size and form of *M. medialis*, Meek and Worthen. The aperture is narrower, however, and the form of its lower angle is different. It is also but little larger than *M. subcorpulentus* of Whitfield, but until figures of the latter appear it will be impossible to compare them.

Macrocheilus sp?

(Plate II, Fig. 2.)

A second species is recognized from a badly flattened specimen, which is perfect enough, however, to show that the species is very like *M. planus*, though in its present condition it seems much more robust. In size and number of volutions it agrees very fully.

Pleurotomaria sp?

Figures 11 and 13 of Plate II, indicate a species of this genus with rather high conical spire and revolving as well as obliquely decussating striæ. I am not able to suggest its specific affinities.

Pleurotomaria newportensis, White (?)

(Plate II, Fig. 18.)

Volutions about five, regularly rounded, very convex, and rapidly diminishing in size; spire short; lower whorl marked by a spiral band originating at a notch in the margin of the aperture, consisting of an elevated striated ridge; otherwise marked with numerous revolving lines of which some are larger than others and separated by one or two of the smaller lines. It is by no means certain that our form is really this species. In the first place, the shell is flattened obliquely by pressure, so as to greatly distort the aperture and otherwise alter the form. Evidently, however, it was a shell of similar form and general appearance with P. newportensis. The striæ differ in being more numerous, though the obliteration of the minuter sort would remove this difference. P. newportensis is further described: Aperture sub-cir-

cular in outline, its margin oblique; outer lip having a broad nc
little above the middle; inner lip thickened. Our specimens in
a species at least a third smaller than White's types.

Euomphalus sp?

(Plate II, Figs. 4, 5, and Plate V, Fig 5.)

A small species is represented by impressions and fragme
the dorsal and umbilical side. About three whorls are preserved,
uring .42 in diameter. The dorsal or upper surface seems
marked by a sharp carina along the outer margin and to have be
namented with strong lines of growth. The umbilical surface
perfectly preserved, but had a series of sharp prominences alo
inner margin and semi-carinate ridges elsewhere. Since writi
above more perfect and larger specimens have been found. Th
cies is also found in the flinty limestone at the top of Flint
The existence of prominences along the inside of the umbilical wh
a constant character, and the revolving lines seem less so.
sharp external carina of the opposite or upper side is also a ch
identical with E. rugosus, but this species differs constantly
presence of the prominences on the umbilical edge of the whor

GENUS LOXONEMA.

(Plate III, Fig. 2.)

A fine species of this genus is known from a single crushed
men which is represented (partly restored) in our figure. The
is 2.20 or more in length, the diameter of the largest whorl
about .75. The spire is elevated and has an apical angle o
The number of volutions can not be less than ten (the termina
are absent in the specimen.) The volutions are convex and are n
by strong, somewhat oblique plications, about seven in half an i
the largest volution. The characters of the lip, aperture and
ella can not be made out, though there is some evidence of a
tion of the lip downward at the lower angle of the aperture.
shell accords in most points which can be made out with L. pli
Whitfield, but, as there are in the neighborhood of twenty des

coal-measure species, many being similar, it is hazardous to identify it certainly with any of them.

LAMELLIBRANCHIATA.

Entolium aviculatum, Swallow.

(Plate I, Figs. 1, 2; Plate III, Fig. 10.)

It is submitted that it is impossible to rescue the Entoliums of the carboniferous from the inextricable confusion into which they have fallen. Nevertheless the name E. aviculatum doubtless applies to a species of wide distribution in the coal-measure rocks, however it may be related to sub-carboniferous species.

The remarks of Prof. Meek, under his description of an Entolium from the Waverly, are instructive as showing the difficulty of discriminating species in this group. He also says "Prof. Winchell's type [of Pernopecten shumardianus] seems to agree exactly, in all constant *specific* characters, with *Entolium aviculatum*, Swallow, already mentioned, from the coal-measures. So we have here a remarkable case of shells presenting extremely little or *no* constant *specific* difference, and yet differing in a character of the hinge that seems to be of *generic* importance."

Although Prof. Hall figures Pernopecten shumardianus from Newark, O., we have found no such form, though another and smaller shell apparently belonging to Pernopecten, is rarely found in the Waverly. We thought for some time that by mistake some Flint Ridge or Bald Hill specimens (coal-measures) had been labeled Waverly, but none of our numerous specimens from the coal-measure shales show the crenulated hinge prominences ascribed to the species in question. Mr. Meek, however, supposed P. shumardianus to be without the crenulated hinge and others have decided that Entolium is synonymous with Pernopecten. If that be the case it is difficult to see how E. aviculatum can be distinguished from Pernopecten shumardianus. The hinge in all specimens seen from the coal-measures shows, instead of a prominence, an impressed line on the left valve, at the point designated in Penopecten by a crenulated ridge, this appears on the *outside* of the valve as a ridge, the shell being very thin. On the ventral valve in the same position is a ridge, designed, it would seem, to fit into the groove of the other valve. The left valve, however, has its ears produced upward so that the hinge line is straight and distant from the groves, while on the right valve the ridge is at the upper margin. Thus Prof. Hall has compared the hinge line of a right valve of Pernopecten limiformis with the left valve of P. shumardianus on Plate I, of the Report of the State Geologist of New York. The projecting ears of the left valve evidently prevent the easy dis-articulation of the valves in this monomuscular form perhaps especially liable to such an accident.

Shell very thin, compressed, very ineqi-valve, height of left valve noticeably greater than width; general outline (without the ears) acutely oval, lower outline a nearly regular curve, extending posteriorly about one third the height of the shell, anteriorly two-thirds the height, posterior margin thence proceeding upward nearly a straight but oblique line to the angle of the ear, but rather abruptly angled near the union of the upper and middle thirds of the height, the anterior margin is strongly curved inward at the same point and thence continued in a line at about the same angle as the opposite side to the ears, which project slightly upward so that the angles formed by the hinge line and the lateral margins are about right angles; position of the hinge of the opposite valve indicated by an impressed groove appearing outwardly as a ridge; ears set off by distinctly marked furrows; valve marked by numerous faint concentric lines and very feeble distant radiating striations.

Right valve as high as wide, its lower margin evenly rounded, the curve continuing on both sides to nearly ⅓ the height, the front side more produced and abruptly curved, front ear longer but less high, so that the hinge line, which is nearly straight, seems oblique to the long axis of the valve.

Entolium attenuatum, sp. n.

(Plate I, Fig. 11.)

A very slender species represented by a single left valve is derived from the flinty limestone at the top of Flint Ridge, and thus 100 feet higher than the horizon of the above named. This species was much more elongated, and had a very narrow hinge. The lower margin is uniformly but strongly curved, while the sides are nearly straight and inclined at a very acute angle to each other. The anterior margin curves somewhat abruptly at its upper third, the posterior margin is straight. The ears are acute and depressed, while the beak is acute and somewhat elevated. There seem to be indications of the hinge ridge or furrow peculiar to this genus. Markings obscure, but apparently consisting of few radiating and many faint concentric lines. Length, 1¼ the greatest width. Hinge somewhat over ¼, the greatest width.

GENUS AVICULOPECTEN.

The literature at command makes an attempt to study the numerous members of this genus rather unprofitable, but in as much as several have been figured we may briefly allude to them.

Aviculopecten hertzeri, Meek

(Plate I, Figs. 5 and 10.)

Specimens corresponding in size and form to Meek's type, are numerous, and occasionally one encounters the same shell of double the usual size, but retaining the characteristic marking. This species may be recognized by the close thread-like concentric and radiating lining producing a peculiar textile structure. This may be seen from the inside of the shell also. In the smaller specimens seen the shell sculpture is somewhat different. The entire shell is covered by strong radiating costæ in pairs, the costæ being closely crowded but separated by deeply impressed grooves between the pairs. These radiating lines are crossed by very fine and numerous concentric striations. The pairs tend also to again bifurcate toward the lower margin. This dichotomous arrangement of the very strong radiating ribs seems to distinguish this form constantly, though it may be, as at first supposed, the younger variety of A. hertzeri.

Aviculopecten? sp?

(Plate III, Fig. 18.)

The shell figured resembles *A? sublobatus,* Phillips, but is still more elongate. It may be that the shell has suffered some distortion, though there little indication of it, and until other specimens are seen it will not do to rely too much on the figure. The left (?) valve figured is elongate, almost linguliform; beak acute, prominent; hinge line less than ⅓ the height of the valve, which is strongly convex near the median line and ornamented with fine radiating and concentric striæ.

Aviculopecten coxanus, M. and W.

(Plate I, Figs. 4 and 17.)

This little shell is not uncommon at Flint Ridge and Bald Hill, and curiously enough is generally preserved so as to expose the interiors, this fact led to some confusion, as the shell is so thin that the markings involves the whole shell and the inside is therefore a negative copy of the outer surface. Our largest specimen is of the size of the specimen figured by Meek, but presents the inner surface. This species may be recognized by the slight obliquity (more than indicated by Meek) and alternating striæ. The striæ seem to be uniformly more prominent than in the type, the striæ are also square in section. The posterior ear is acute with its posterior outline concave, less distinctly separated from the valve than the anterior ear, which is less acute. Length, .50; width, .49; hinge line, .40. About 14 primary striæ on the body of a valve of this size with alternating minute ones.

Aviculopecten scalaris, sp. n. ?

(Plate I, Fig. 8.)

We have been tempted to regard this as a form of A. occidentalis, but there is a marked dissimilarity in the markings. The shell is equivalve, the valves nearly alike; somewhat longer than wide; hinge line shorter than greatest width ; lower margin a uniform curve ; front margin strongly curved, anterior ear separated from the body of the shell by a sharp depression ; posterior ear larger, more excavated on its lateral margin and less distinctly marked off from the valve The valves are marked by fascicles of triangular, prominent striæ or ridges, which increase by bifurcation, usually with a feeble preference for dichotomy; these ridges crossed by sharply marked concentric angular depressions causing a resemblance to the treads of a stairway ; also concentric lines most prominent upon the ears. The coarser wrinkles might have been thought accidental, but for the constancy with which they appear. After making the corrections indicated by Meek (Geological Surv. Neb., p. 192) in the figure of Geinitz, the dissimilarity in form is very slight and it is suspected a wider comparison would prove these shells identical.

Aviculopecten sorer, sp. n.?

(Plate I, Fig. 7, and Plate III, Fig. 16.)

We have a number of specimens of a fine species remarkable for the beauty of the surface markings, but all too imperfect to very satisfactorily characterize. The form, exclusive of the ears, is sub-triangular, both anterior and posterior margins being concave or nearly straight. The greatest breadth is below the middle and the lower margin is a uniform, rather shallow curve. The ears are large and sub-equal, the anterior are (?) most acute. Shell ornamented with prominent distant ribs separated by three or more smaller ones, all being nodose in the path of concentric markings or, rather, the nodose character produces the effect of concentric lines crossing the striæ. This shell resembles A. scalaris in general configuration very closely, more closely than indicated by the description, but it seems to vary greatly. The nodose character is also variable. No perfect specimen has been found, but many fragments indicate a species about the size and form of A. scalaris, with rounded distant striæ, separated by crowded finer ones. The ears are broken in all the specimens seen, but we presume the valve, Fig. 16, Plate III, is opposite to that of A. scalaris Fig. 8, Plate I, and so there is a slight difference in outline.

Aviculopecten sp?

(Plate I, Fig. 6.)

A little shell similar in outline to A. (Crenipecten) leon, Hall, is known from the single valve figured. It is peculiar in the relatively very short hinge and restricted ears, as well as in the ornamentation which consents of sharply defined, though small, ribs arranged in rather distant pairs. The specimen is a left valve and rather oblique. The general outline is acutely ovoid, the beak being nearly central and quite prominent. The posterior ear is very small and acute, anterior ear larger, with a more concave outline.

Crenipecten Foerstii, sp. n.

(Plate III, Fig. 9, 9a.)

The species figured is, next to Entolium aviculatum, the most common bivalve at Flint Ridge, and finds its counterpart in Streblopteria (?) tenuilineata, M. and W. Indeed, it is not improbable that the two are identical, in spite of marked points of divergence. It would be impossible to reconcile the description of that species with our specimens, while Meek's drawings are equally different. The reference to Streblopteria is certainly erroneous, although it is fair to add that Meek and Worthen had not seen the hinge. The genus Crenipecten, as defined by Hall, includes a diversity of forms ranging from such symetrical, long-hinged species as C. Winchelli to those oblique species represented by C. amplus and our own. A single specimen (Fig. 9 a.) from Mr. Foerste's collection, gave evidence of the crenulated hinge area, from the impression, the shell having been exfoliated. The characters of Streblopteria are as follows:

"Shell ovate or rounded, obliquely extended towards the anterior side; posterior wing broad, undefined, nearly rectangular, extending nearly as far as the posterior margin of the shell; anterior ear small, deeply defined; surface smooth or radiately ridged; one large, faintly marked, muscular impression a little behind the middle; one short, narrow tooth slightly diverging from the hinge on the posterior side of the beaks; ligament confined to a narrow, simple facet on the hinge margin."

In comparing our specimens with the figure of S. tenuilineatus we find, aside from its greater average size and different markings, that the anterior margin is more produced, and the anterior ear is much more sharply defined. There is little doubt that the two forms are at least congeneric.

Shell below the ears subcircular, but moderately convex, equivalve. Right valve with the anterior ear produced, rounded in front, separated from the valve by a deeply impressed, concave auricular sinus; posterior ear nearly rectangular, slightly concave in posterior outline, separated from the valve by an impressed line; hinge line one half the height of the valves. Left valve of same form, but the ears less distinctly separated: hinge line less than half the height, anterior ear with concave front outline. The beaks are acute and moderately prominent. Surface marked by numerous close, minute, concentric lines, and numerous irregular, concentric wrinkles which give a peculiar appearance to the shell, not shared by other species. These wrinkles are less marked on young shells. There are also, in most cases, indications of radiating lines, which in the larger shells are strong striæ or ribs, at a distance from each other. Length of mature specimen .70, width, a trifle less, hinge of right valve, .34. A very similar, or probably identical form, occurs in the Waverly, which may prove to bear a name ranking the one now proposed.

GENUS LIMA.

Lima retifera, Shumard.

(Plate IV, Fig. 25; Plate V, Fig. 3.)

Shell obliquely subovate; posterior side short; anterior side obliquely produced; cardinal border rather short; lower margin a nearly uniform curve; anterior margin nearly equal, anterior one obtuse in outline, posterior ear rectangular; surface of valves marked by strong angular radiating costæ and concentric striæ. Height .50; length .70. Our specimens were, for the most part. very small, but otherwise agree with the description of this species, which is widely though not abundantly distributed.

Roemer, in his paper entitled "Ueber eine marine conchylien-Fauna im Steinkohlengebirge Oberschlesiens," figures a little shell, very much like this, but somewhat less oblique. He identifies it with a query, with Pecten interstitialis, Phillips.

GENUS SOLENOMYA, Lam?

The generic reference is here very doubtful. Two of the forms are evidently closely allied, while the other might probably be more properly referred elsewhere, if we knew anything of its hinge.

1. *Solenomya (?) anodontoides,* Meek.

(Plate IV, Fig. 10.)

This form agrees with Meek's description and figures, except that the anterior margin is much less acute, that portion of the shell not extending into a heel-like prolongation below, as represented in his figure. The anterior margin is subtruncate in some specimens, and the lower margin is nearly straight and parallel with the axis of the shell; the posterior margin is evenly curved, the greatest convexity being in the middle of the height of the shell. The largest specimen measures 1.20 in length and .75 in width, the smallest, 1.12 by .66.

The surface in each was covered by rather strong, variable, concentric lines. The middle of the valve is nearly uniformly convex, sometimes with a shallow depression extending from near the beak to the lower margin; shell slightly gaping behind.

2. *Solenomya (?) meekiana, sp. n*

(Plate IV, Fig. 9)

This is a much more elongated species or variety, otherwise almost identical, though the specimens observed were all smaller. Nearly quadrate, elongate, more than twice as long as wide; sides parallel, straight; posterior outline gently curved; anterior outline somewhat truncate, not produced; convexity somewhat greatest near the beak, but entire valve nearly equally convex, sloping gently and almost equally to the entire margin. Length, 1.05, width, .50. Surface marked as in the previous variety. Although Meek (Geol Surv. Neb. p. 233; Plate IV, Fig. 7,) refers to Edmondia a species almost certainly identical with ours, as E. reflexa, comparison with the typical form, shows that it is far from probable that the specific reference (if the generic) could be sustained. It may be better to apply a new name, as suggested, and await farther evidence as to the relation to S. anodontoides.

Solenomya subradiata, sp n.

(Plate III, Fig. 8.)

This species somewhat resembles S. radiata, M. and W., but is much more elongated and expanded posteriorly. The shell is very thin and is somewhat compressed in the only specimens seen. Very narrowly oval and slightly convex; posterior dorsal line straight; posterior margin a regular curve; lower margin a uniform slight curve; umbo 4-5 the length from the posterior extremity, anterio-dorsal line convex, inclined abruptly from beak; anterior part of shell produced below in a strong "heel." Surface with very obscure concentric lines and still more faint equidistant radiating lines. These latter are not very numerous and could easily be overlooked. Length 1.20, width .45.

The radiating striæ or impressed lines do not spring from the beak, but seem to terminate in the posterior hinge line; they are only obvious on the posterior third of the shell.

GENUS MACRODON, *Lycett.*

1. *Macrodon obsoletus,* Meek.

(Plate IV, Fig. 19.)

Shell elongate sub-quadrate or sub-rhombic, moderately convex, greatest convexity forming a gentle prominence extending from the umbo to the lower posterior margin. Upper posterior portion nearly plane, inclining gently to the obliquely truncated posterior margin; this part of shell only marked by faint radiating striæ. Hinge line straight, parallel to it two or three impressed lines separating the teeth, these showing in the partially denuded shell figured. Beaks removed but a short distance from the front margin. Anterior margin gently curved, meeting the hinge line by an abrupt right angle. Lower margin nearly straight or slightly convex. Entire surface marked by few concentric lines of growth.

2 *Macrodon tenuistriata,* M. and W.

"Shell small, rhombic-oblong, rather distinctly convex along the umbonal slopes and near the front, a little more than twice as long as high; basal and cardinal margins parallel, the former nearly straight or somewhat sinuous near the middle; cardinal margin straight, not quite equalling the greatest antero-posterior diameter; anterior side rounding up from below so as to meet the hinge nearly at right angles; posterior basal margin narrowly rounded; posterior margin obliquely truncated, often a little sinuous above; dorsal region behind the umbonal slope compressed; beaks compressed, a little flattened, incurved and rising somewhat above the hinge margin, located about half way between the middle and front; flanks broadly impressed or concave from the umbonal region obliquely backward to the faintly sinuous part of the base; surface ornamented by distinct marks of growth radiating markings, well-defined behind, forming anteriorly crow bsolescent striæ."

Our specimens are smaller than those described by Meek, and more convex, but otherwise they agree. Length, .36, height, .16. This shell is almost identical in outline with M. obsoletus, but is much more gibbous. The possibility that it is merely the young of that species cannot be disputed.

3. Macrodon carbonaria, Cox.

(Plate IV, Figs. 21 and (?) 14.)

This is a very pretty and somewhat common species. It is easily recognized by the strong radiating ribs which are much more prominent in the area marked off by the posterior umbonal ridge. The largest specimen measures 1.40 long by .625 wide, and is truncated obliquely behind. The concentric markings are plainly seen.

Figure 14 shows the inside of a valve which, from the inferior size and projecting anterior margin, could be identified with M. tenuistriata, M. and W., though, as the shell is but a fragment, it would be venturesome.

GENUS PROTHYRIS.

Prothyris (cf. *elegans,* Meek.)

(Plate IV, Fig. 3.)

The specimen on which this identification rests is imperfect and the anterior is not fully preserved. The description of the species is as follows: "Shell compressed, elongate oblong, the length being about three and a half times the height; ventral and dorsal margins straight or a little arched; the latter with a faintly defined marginal furrow, below which there is usually an obscure ridge, also parallel to the dorsal margin; posterior extremity obliquely sub-truncate, the most prominent part being below the middle; beaks compressed, depressed, not distinct from the dorsal margin, and placed about one-eighth or one ninth the length of the valves behind the anterior extremity; notch of the anterior margin well-defined and extending about one half way up to the beaks; ridge from the inner angle of the notch narrow, flat, widening slightly from above; anterior margin above the notch rounded, and having the appearance of a flattened ear; surface striæ nearly obsolete on the upper half of the valves, and more distinct on the ventral and antero-ventral regions."

GENUS ALLORISMA.

Allorisma costata, M. and W.

(Plate III, Fig. 7, and Plate IV, Fig. 28.)

We have not been able to compare this fine species with types, but in spite of its great dissimilarity, notably in size, from specimens referred to this species by Mr. Meek, we regard this as identical with the Illinois species. The generic reference is far less satisfactory. Indeed, it is suspected that an examination of the hinge would prove this an independent genus.

Shell medium sized, elongate; upper and lower margins sub-parallel; beak prominent, anterior; anterior margin short, convex; shell produced and slightly attenuated posteriorly, posterior margin sub-truncate; greatest depth of the shell a little posterior to the umbo; surface marked with (12) strong, distant concentric costæ extending from the anterior margin to the prominent posterior umbonal ridge, where they abruptly cease. The surface above the ridge being marked by fine concentric lines and a well marked ridge extending from the beak toward the centre of the posterior margin. Our specimens embrace impressions as well as the right valve. The space between the costæ is gently concave and smooth and there seems to have been a radiating rib upon the summit of the umbonal ridge into which the concentric ribs merge. There are indications of an impressed line along the hinge line posteriorly. The outline of the posterior margin seems in the best preserved specimen, bi-truncate, in others obliquely truncate in one straight line; other minor differences are referred to the conditions of preservation. Length, 1.40; height, .50. Comparisons were drawn in our note book with Orthonota, to which it may be allied.

Allorisma Geinitzii, Meek. (?)

(Plate IV, Fig. 27.)

This small species resembles, somewhat, A. gilberti, White, though it is by no means so much produced posteriorly. Shell very small, elongate; not very gibbous; anterior dorsal margin inclined from the beak to the anterior end of the evenly curved lower margin, with which it united by an acute angle; posterior dorsal margin gently sinuous, four times as long as the anterior; posterior margin somewhat obliquely truncate, more prominent below; greatest height at the umbo, posterior part somewhat narrowed. Surface marked by irregular concentric striæ and, at least posteriorly, by a few indistinct radiating lines. Length, .33, height, .17. It is more probable that this species is new, but some hesitation is felt in separating it from a minute form of nearly the same outline, in view of the poverty of our material and the variability of the species.

Allorisma subcuneata, M. and H.

(Plate IV, Fig. 1.)

I am by no means certain regarding the identification of the fragments which have been referred to this species. However, it is certain that a shell of about the same size and having the same form about the umbo and the same coarse markings is found at Flint Ridge. The species, moreover, is widely distributed, occuring in Utah and New Mexico, as well as Indiana and others of the central states. The description is as follows: Shell large, twice or more times as long as high, gibbous anteriorly, compressed posteriorly, where the valves gape somewhat; basal margin nearly straight, curved rapidly near the anterior, more slowly at the posterior ends; dorsal margin convex posteriorly, giving the posterior outlines a somewhat spatulate form; front margin rather narrowly rounded; beaks projecting well beyond hinge line; surface marked by well defined concentric lines. Length, nearly four inches.

GENUS CLINOPISTHA.

Clinopistha radiata, Hall.

(Plate III, Fig. 11.)

Our specimen was associated with the forms elsewhere referred to Edmondia aspenwallensis, and resembles them very nearly. The outline differs perceptibly, however, and the faint and very rugular concentric striæ are quite unlike the folds which ornament the shell of

Edmondia. No traces of radiating lines are preserved, but the condition is such as to explain their disappearance.

Our specimen is rather less ventricose than that figured by White, but is also smaller. Length, .52, height, .40.

GENUS PLEUROPHORUS, King.

1. *Pleurophorus tropidophorus*, Meek.

(Plate IV, Fig. 15.)

This pretty shell is not uncommon at Flint Ridge. I am not sure that there are not two closely related species differing chiefly in size.

2. *Pleurophorus subcostatus*, M. and W. (?)

(Plate IV, Figs. 16 and 16a.)

We have a number of small specimens which vary so much among themselves that the variableness may account for some discrepancies between them and the description of Meek and Worthen. Ours is a smaller form and the larger examples have the sinuous lower outline of P. subcostatus. A very much smaller and more compact form figured on the same plate, Fig. 7. may be the young of the same species.

GENUS CYPRICARDINA, Hall.

Hinge unknown, shell elongate trapezoidal, moderately compressed, beaks anterior or sub-anterior, slightly prominent, surface marked by rather prominent concentric plications or striæ. (Hinge with well developed hinge-plate, with one linear tooth in one valve and two in the other, and other minute linear teeth shorter than the others, *Synopleura*, Meek.)

Cypricardina (?) *carbonaria*, Meek.

(Plate IV, Figs. 17 and 18.)

This shell was described from the locality whence our specimen came, so that it may be best simply to quote the description given by Meek: "Shell small, longitudinally oval, less than twice as long as high, the widest (highest) part being under the posterior extremity of

the hinge; rather gibbous, usually with a broad impression exte
from the beaks obliquely backward and downward to the mid
the base of each valve; anterior side extremely short, or nearly
lete, convex, and rounded; posterior side broader, more comp
or cuneate, with its upper edge straight and sloping obliquely
ward to the regularly rounded posterior margin; base broadl
slightly sinuous in the middle, and rounding upward at the extre
hinge line straight, between one-half and two-thirds as long
valves, ranging at an angle of about 25 deg. with the oblique,
axis of the shell, so as to meet the sloping upper edge of the po
margin at a very obtuse but moderately well-defined angle, th
parting to the somewhat compressed posterior dorsal region a
faintly alate appearance; beaks extremely oblique, depressed
to the dorsal margin, very nearly terminal, and scarcely projecti
yond the rounded outline of the anterior extremity. Surface
mented by fifteen to twenty exceedingly regular, well-defined, s
bricating, flattened ridges or undulations, that gradually become
er and more closely approximating on the umbones. Length o
est specimen seen 0.55; height at the posterior extremi
hinges .32."

The specimen figured is but 0.45 long, but agrees well wi
description, it being a partial cast, showing hinge teeth distinctl

Gervillia (?) ohioense, sp. n.

(Plate IV, Fig. 13, and Plate III, Fig. 12.)

(Cf. *Avicula longa*, Meek.

Two specimens have been secured from Flint Ridge, both
what imperfect, but indicating a species quite different from M
teria gibbosa. The whole question of the generic affinity of th
boniferous species referred to Gervillia, Monopteria, Blakevellia
is very obscure.

The upper outline is nearly straight; beak distant nearly on
the length from the anterior margin; posterior wing greatly prod
posterior margin deeply sinuous; posterior, produced part of
keeled; anterior wing acute, its margin very oblique and slightly c
to its junction with the lower margin, with which it forms a cont
symmetrical curve. Hinge line, .65, height, .45, greatest length

The surface is marked by rather obvious concentric lines. The postero-inferior projection is greater than that of the hinge line. Fig. 13 of Plate IV, represents a specimen in which part of the posterior outline is obscure, while that figured on Plate III, Fig. 12, had its antero-inferior outline crushed in. By combining the figures a fair idea of the shell can be obtained. The specimen figured on Plate IV, is much flattened and somewhat distorted, it should be restored by producing the upper, posterior angle and the lower, posterior lobe. From *A. longa*, which it most resembles, it differs in being not only larger, but less produced posteriorly, the posterior sinus is much less and the anterior part of the shell does not appear to have the oblique sulcus described for that species. (We have, since writing the above, found the long posterior tooth characteristic of Avicula.)

Myalina (cf. recurvirostris, M. and W.)

(Plate V, Fig. 4.)

A single fragment indicates a species of nearly the size of the species quoted. It is not sufficient, however, to furnish the basis for accurate identification. The outline probably is not correctly restored in our drawing, but the shell was flattened, causing uncertainty as to the natural course of the striæ. The surface is marked by very coarse but regular and distant furrows, as well as the finer concentric lines.

Myalina sp?

(Plate IV, Fig. 20.)

Only a small fragment was found to indicate a species like M. Meliniformis, M. and W. It belongs to the group of M. subquadrata, M. sublamellosa, Eldridge, M. perattenuata, Meek, M. Flemingii, King, etc., but is a very small species, with acute beaks and strong striæ.

Myalina (?) swallovi, McChesney.

(Plate IV, Fig. 6.)

This familiar and widely distributed species is common here also. The general aspect is unlike most species of Myalina, but more like

Modiola. The surface is marked by few indistinct concentric

GENUS AVICULOPINNA, Meek.

" Very elongated subtrigonal, equi-valve, with slightly ind
sub-terminal beaks, the shell being produced in front of them,
posteriorly ; hinge line very long, edentulous."

1. *Aviculopinna americana*, Meek.

(Plate I, Fig. 20.)

Our fragmentary specimen is insufficient to warrant a descr
but is obviously a member of the old genus Pinna. In size and
tainable characters it seems to correspond with the species
above. We are unable to discover that the beaks are not anteri
this may be due to the imperfect condition of the fossil. The c
ter of the ligament grooves is well shown in this specimen. Th
tangible distinction between Pinna and Aviculopinna being the
tion of the umbo, the generic reference is but provisional.

Solen? sp?

(Plate I, Fig. 19.)

We have figured a fragment which seems to indicate a Raso
about as completed in outline in the drawing. The piece is too
to characterize, but attention is called to it to stimulate collect
examine the rocks for more complete specimens.

Edmondia (cf. aspinwallensis, Meek)

(Plate IV, Fig. 4,; Plate III, Fig. 17.)

We have a considerable number of specimens of various
but all of the larger individuals are imperfect, while the smalle
differ considerably from the species quoted. The shell is covere
strong concentric folds and very numerous striations. The po
margin is broadly and evenly rounded (sub-truncate in the larger
the beaks are not prominent; the lower outline is a regular
the anterior margin seems much shorter than in types of E. aspi
ensis; the convexity is greatest in front and above the middl
there is sometimes a posterior umbonal ridge, nearly reaching th

gin. Hinge and beaks not clearly seen. Length of small specimen, .55, height, .50; larger specimen, .85 by .70.

GENUS ASTARTELLA.

Astartella Newberryi, Meek.

(Plate IV, Fig. 33.)

This species is very abundant and varies in size greatly, but adheres strictly to the same type.

Astartella vera, Hall. (??)

A species about the same size as the last is less abundant, it seems to correspond with the form figured in the second vol. of Ohio Paleontology, Plate XIX, Fig. 1. It differs in outline from the latter, but the shell figured was evidently broken, as shown by the direction of the concentric ribs, the posterior wing being broader than represented. It differs from A. Newberryi, chiefly in the somewhat coarser striæ.

Astartella varica, McChesney.

(Plate IV, Fig. 31.)

This species is not very well represented in our collections. It attains as great or greater size than A. Newberryi, but is more flattened, with only a slight posterior umbonal ridge, but the specimen figured in the Ohio Paleontology, was evidently badly flattened, as the umbonal ridge is much more distinct than there represented. Several of our specimens were in the same state of preservation.

GENUS MICRODON, Conrad.

The reader is referred to the discussion of this genus, in the 13th Annual of the Indiana State Geologist. It seems very probable that our specimens are generically if not specifically identical with the little shells found in the Spergen Hill, Indiana, limestones.

Microdon (*cf. subelliptica*, Hall)

(Plate IV, Fig. 32.)

Both valves are preserved and are nearly alike. Shell very small, somewhat trapezoidal, obliquely truncate behind, height over four-fifths the length, gently and evenly convex; dorsal margin, behind the beaks nearly straight, the gently concave cardinal margin forming nearly a right angle with it; lower margin a uniform curve. Posterior umbonal region evenly convex, but with evident ridge. The surface of the shell is marked by fine yet distinct concentric lines, there being about 21 upon a shell .20 high. Although the hinge has not been seen it seems reasonably sure that the generic reference is correct, making the first instance we remember of its occurrence in the coal-measures.

GENUS NUCULANA.

Nuculana bellistriata, Stevens.

(Plate IV, Fig. 26.)

This very pretty shell is abundant. Our specimens are much smaller than the types. They resemble in form and markings the European Leda attenuata, yet probably are correctly identified with the West Virginia species. The species occurs also in Indiana.

GENUS SCHIZODUS, King

Shell trigonal, rounded anteriorly, attenuated behind, [illegible] smooth, with an obscure oblique ridge; ligament external; hinge [illegible] 2-3, rather small; anterior adductor slightly impressed, remote [illegible] the hinge, with a pedal scar close to it; pallial line simple.

The reference of species to this genus upon the evidence of external form alone, can only be provisional. There are over [illegible] species of fossil forms attributed to this genus.

Six species from the coal-measures of this country are described, while there seem to be at least four forms among the specimens received from the shales at Flint Ridge. It is frequently [illegible] [illegible] specimens are liable to distortion, especially [illegible] [illegible] these, which are usually more or less flattened [illegible]

American species are S. cuneatus, wheeleri, amplus, perelegans, occidentalis, and curtus.

1. *Schizodus affinis, sp (?) n,*

(Plate IV, Figs. 22 and 22a.)

This species is represented by nearly perfect casts of both valves, which are similar in form though various in size. The description will refer to the specimens rather than the species they represent. Right valve ovate, sub-trigonal, greatest convexity being about one-third from beak and one-third in length; anterior margin broadly curved, its curve varying littie from an arc of a circle, a little truncated above; lower margin much less curved to the sharp angle at its posterior extremity, which is produced as the termination of a prominence beginning at the umbo as a sharp ridge extending as a low fold to the margin; posterior margin slightly convex, inclined forward entering the upper margin by a gentle curve. The beak is distant one-third the greatest length from the anterior margin and is but moderately convex. Surface apparently with fine concentric lines and deeper lines of growth. Length, 1.20, width, 1.03; convexity apparently not over 0.50.

Schizodus cuneatus, Meek, differs most notably in the position of the beaks, which are located only one-quarter from the anterior margin, and as a result, the posterior part of the hinge line is much longer and the anterior broad margin as seen in our shell is absent. Our specimen as figured is possibly somewhat flattened.

2. *Schizodus sub-circularis, sp. n.*

(Plate IV, Fig. 24.)

A still smaller species or variety from the same rocks differs chiefly in having the beak near the middle line of the shell. It is known from a single left valve. The anterior and lower margins are continuous parts of almost a circle, which is only a little produced posteriorly; the posterior margin is inclined; beak sub-median, posterior umbonal ridge not sharp. The shell is moderately convex and is nearly smooth, except for the distant lines of growth. Length, .63, width, .59, convexity, about .20 (single valve).

3. *Schizodus wheeleri*, Swallow.

(Plate III, Fig. 15.)

This species is identified beyond question and is recognized by the great prolongation of its posterior side. The beaks are prominent and situated over one-quarter the length of the shell from the anterior margin. The anterior part of the shell is moderately convex, while that posterior to the sharply defined ambonal ridge is greatly compressed. The lower margin is very long and evenly convex, terminating posteriorly in a prominent acute angle; posterior margin obliquely truncate; dorsal margin deflected posteriorly. Length, 1.20; height, .80. Surface marked by very fine concentric lines.

4. *Schizodus cuneatus*, Meek. (?)

(Plate IV, Fig. 23.)

It is very strange that the original localities of this species have yielded us four species besides, but no typical example of that one. The fragment drawn is referred here only because it indicates a species produced posteriorly somewhat and different from S. wheeleri. I am inclined to believe that S. cuneatus is not a valid species.

5. *Schizodus curtus*, Meek and Werthon.

A single specimen, showing parts of both valves, agrees most nearly with this species, but is more like a form figured by Meek, U. S. Geol. Surv. Neb., Plate X, Fig. 13d. This he says is probably a different species. In *S. curtus* the lower margin is straitened in front of the umbonal ridge, in this the regular curve is continued. *S. curtus* is so variable that it is not impossible that our species is identical.

6. *Schizodus* (?) *spellmani*, *sp. n.*

(Plate III, Fig. 14.)

A very perfect left valve collected by Mr. Spellman, forms the basis of this description. The shell is larger than either of the above, but falls short of the maximum of S. cuneatus, which it somewhat resembles. The margin valve is subelliptical, and moderately and evenly rounded; ventral margin forming a perfect semi ellipse; posterior side long, posterior margin rounded, beaks moderately prominent.

rounded, at least one-third length of valves from anterior margin; hinge line straight behind the beak; posterior umbonal ridge rounded, not carinate; surface with imperfectly preserved fine lines of growth. This species obviously differs from the three above described. It would seem to resemble *S. amplus*, but in that the posterior margin is said to be vertically sub-truncated, also the posterior umbonal slope has a distinct sulcus not seen in this species.

Genus Placunopsis, Morris and Lycett.

Placunopsis recticardinalis, Meek.

(Plate IV, Fig. 11.)

This species was described from Flint Ridge and hence the figure given by Meek is copied, although we have not found the shell as yet.

Genus Posidonomya, Brown.

Posidonomya fracta, Meek.

Only fragments of this shell which, as Meek says, is almost an exact miniature of the cretaceous Inoceramus problematicus were found.

BRACHIOPODA.

Lingula tighti, *sp. n.*

(Plate IV, Fig. 5.)

This name is proposed for a Lingula of medium size found in great numbers upon the lamellæ of earthy portions of fissile cannel coal at Flint Ridge, ten miles east of Newark, Ohio. This coal seam is number two in the section and has furnished considerable quantities of fairly good coal to local consumers. The Lingulæ occur in great numbers, covering the surface in places completely, and the coal is filled with them for a thickness of several inches. Valves nearly similar, elliptical, somewhat asymetrical; one margin nearly straight, the other more strongly curved, sides narrowed anteriorly and then rather abruptly rounded; width equal to over one-half the length; beak nearer the straight margin; shell covered with brown, finely striate epidermis, which is well preserved; striæ very numerous, crowded, but regular, somewhat umbricated about the beaks. Length, .50-.60; width, .30.

This sp es resembles rather closely L. melie, Hall, but is not narrowed toward the beaks as much as in that species, neither has it the rather prominent mesial sinus. Our species is more oblique in front.

The European *L. mytiloides* is also very similar, but seems to be uniformly smaller and more nearly resembles *L. melie* than our specimens. Named for the discoverer Mr. Wm. G. Tight, of Granville. We have thought this a possible variety of L. umbonata, Cox, a shell common in the coal-measures. It is nearly of the same size, but is relatively longer and the margins do not approach each other above as rapidly. It is quite char species that the breadth of the shell at one-fourth the aks is equal or even greater than the width at the same d he front margin. The occurrence of this Lingula in can ng with broken fern fronds supports the theory that it was er water by debris brought in by streams or otherwise.

Athyris s Hall.

(Plate 1,)

This common and widely dist species seems not to be abundant in the rock under cons only a few specimens having been secured.

Shell somewhat ovate, longer than broad, front margin nearly circular; valves very nearly equally inflated; ventral valve rather more convex, the greatest convexity being one-third the distance from the prominent arched beak; mesial sinus obscure, except toward the front of the valve, hypodermis marked with radiating lines which sometimes appear through the shell, especially that at the bottom of the sinus; epidermis marked by concentric lines of growth; dorsal valve uniformly convex, without evident fold and with short approximated beak. The radating lines on the dorsal valves are less regular—they are simply lines impressed upon the shell by the viscera.

Spirifera opima, Hall.

(Plate II, Fig. 23.)

Shell rather small, moderately convex, nearly semi-circular to transversely oblong, variable. Ears and middle of ventral margin rarely salient. Hinge line nearly or quite equal to the greatest width of valves. Ventral valve evenly arched, most prominent one-fourth distance from beak to ventral margin; lateral portions rounded, not reflexed; beak moderately prominent, considerably incurved; area of medium size, marked with numerous obliquely upright ridges; foramen rather broad; mesial sinus rather sharply triangular in section, but not very deep, bearing a medial and four lateral plications, which are also impressed upon the cast, but do not extend to the beak, however; costæ of the lateral slopes of the valve triangular in section, moderately large, varying in number between 10 and 14, usually not bifurcating, but occasionally increased by implantation, costæ toward the lateral margins, merging into the area before reaching the beak. Dorsal valve rather less convex, greatest prominence being nearer the middle than in the ventral valve; beak projecting slightly, incurved; mesial fold about in correspondence with the sinus, bearing five or six simple or bifurcating costæ. The form of the cast of the ventral valve is sufficiently illustrated by our figure, also the fact that in this species the hinge area of the ventral valve is ribbed—a point hitherto unnoticed.

Spirifera camerata, Morton.

(Plate II, Figs. 22.)

This is the commonest Spirifer and one of the most characteristic fossils of the coal-measures. It is found rarely at Flint Ridge and Bald Hill in specimens of rather more than medium size.

Shell somewhat trihedral, the hinge line being longer than any other part, often pointed or mucronate. Ventral valve arched, with a prominent incurved beak; area concave, not very acute toward the extremities, with an almost equilateral foramen, which is partly closed by a pseudo-deltidium; the mesial sinus is deep, triangular in section, continuous from the beak to anterior margin. Dorsal valve less convex; mesial fold well defined, high; sides of the valves nearly uniformly inclined to the lateral margins, beak small, slightly produced. Both valves covered with moderately strong radiating ridges which soon increase by division, the cetral one remaining strongest so that they are grouped in fascicles of from three to five; striæ covering both sinus and fold; shell also marked by concentric ridges.

Spirifera, sp?

(Plate II, Fig. 6,)

A very transverse species is indicated by the cast figured, whi can not be identified with any known coal-measure species. The n ture of the specimen forbids making it the subject of a formal descri tion. It is clearly related to Waverly forms.

SUB-GENUS MARTINIA, McCoy.

Dorsal margin shorter than the width of the shell, the angles the hinge-margin shortly rounded; surface smooth or with puncta (spiniferous?) concentric lines, often with less distinct sub-epiderm radiating striæ; spiral lamellæ small.

Species of this group appear in the Silurian and continue into t carboniferous.

1. *Spirifera (Martinia) planoconvexa*, Sch.

(Plate I, Fig. 12.)

This little shell was found but once in the shales above the Fli Ridge coal. It is one of the commonest and most widely distribut coal-measure species, very possibly identical with *S. Urii*, Fleming, Great Britain.

Length and breadth nearly equal; the lateral and lower (fro margins forming a continuous arc like a segment of a circle; vent valve rather tumid, being most convex near the middle; beak p duced beyond the hinge line, incurved; foramen narrow; area co cave; dorsal valve flat with minute somewhat incurved beak; surfa of both valves granular, with few, rather indistinct concentric lines.

2. *Spirifera (Martinia) lineata*, Martin?

(Plate I, Figs. 13a, 13b, 13c.)

The second species is considerably larger than the first, indeed is not certain that two species are not here confused. That figured Plate III, Fig. 23, was imperfect, but so far as preserved seemed agree with S. lineata, as identified by American writers. In t specimen, which was largely denuded of the shell, the radiating str were very evident and yet on such portions as still retained the sh the concentric markings were much more prominent. A peculiar feature is the existence of two rib-like costæ, extending from the beak to the front margin of the valve, which costæ pertain to the sub-epidermal part of the shell rather than the surface. Our second specimen, as figured on Plate 1, is nearly circular in outline and with very little evidence of radiating striæ, while the concentric markings are very prominent. This form may be distinguished from S. planoconvexa by the great convexity of the dorsal valves, as well as its greater size and the prominence of the beak of the ventral valve. Length, 14 mm, breadth, 13 mm., convexity, 8 mm.

Productus Cora, Owen.

(Plate II, Fig. 26.)

Productus cora, Owen, Geol. Rep. Iowa, etc. Pl. V, Fig. 1. 1852.
Productus semireticulatus, Hall. Stansbury's Rep. Salt L. 411. 1852.
Productus Prattenianus, Norwood. Journ. Acad. Phila. iii, 17. 1854.
Productus œquicostatus, Shumard. Geol. Rep. Missouri, 201. 1855.
Productus cora, Marcou. Geol. N. A. Pl. VI. Fig. 4. 1858.
? *Productus lævicostus*, White. Journ. Bost. Soc. N. H., VII. 1860.
Productus Flemmgii, Geinitz. Carb.-format. u. Dyas in Nebraska, 52. 1866.
Productus Calhounianus, Geinitz (not Swallow) do. 1866.
Productus Konnickeanus, Geinitz, (not de Verneuil) 1860.
Productus Prattenianus, Meek. U. S. Geol. Surv. Net. 1872.
Productus Prattenianus White. Rep. U. S. Surv. 100 Mer. 1877. Also referred to in Ohio Geology as *P. aequicostatus*.

This is the most abundant species of productus in the Carboniferous of Licking county, making up almost the mass of the rock in many places, so that slabs may be secured whose entire surface is studded with the remains of this fossil. Yet, from the fragile character of the shell, it is rarely found not destroyed or broken. I transcribe Shumard's original description as a basis for the study of our forms.

"Shell large, broad, hinge-line equal to the greatest width of the shell. Dorsal valve much elevated, arched, visceral portion slightly flattened on the middle, sides falling rather abruptly to the ears. Ears large, triangular, with three or four broad folds, which are not con-

Spirifera, sp?

(Plate II, Fig. 6,)

A very transverse species is indicated by the cast figured, which can not be identified with any known coal-measure species. The nature of the specimen forbids making it the subject of a formal description. It is clearly related to Waverly forms.

SUB-GENUS MARTINIA, McCoy.

Dorsal margin shorter than the width of the shell, the angles of the hinge-margin shortly rounded; surface smooth or with punctate (spiniferous?) concentric lines, often with less distinct sub-epidermal radiating striæ; spiral lamellæ small.

Species of this group appear in the Silurian and continue into the carboniferous.

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Length and breadth nearly equal; the lateral and lower (front) margins forming a continuous arc like a segment of a circle; ventral valve rather tumid, being most convex near the middle; beak produced beyond the hinge line, incurved; foramen narrow; area concave; dorsal valve flat with minute somewhat incurved beak; surface of both valves granular, with few, rather indistinct concentric lines.

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(Plate I, Figs. 13a, 13b, 13c.)

The second species is considerably larger than the first, indeed, it is not certain that two species are not here confused. That figured on Plate III, Fig. 23, was imperfect, but so far as preserved seemed to agree with S. lineata, as identified by American writers. In this specimen, which was largely denuded of the shell, the radiating striæ were very evident and yet on such portions as still retained the shell the concentric markings were much more prominent. A peculiar feature is the existence of two rib-like costæ, extending from the beak to the front margin of the valve, which costæ pertain to the sub-epidermal part of the shell rather than the surface. Our second specimen, as figured on Plate 1, is nearly circular in outline and with very little evidence of radiating striæ, while the concentric markings are very prominent. This form may be distinguished from S. planoconvexa by the great convexity of the dorsal valves, as well as its greater size and the prominence of the beak of the ventral valve. Length, 14 mm, breadth, 13 mm., convexity, 8 mm.

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Productus Prattenianus, Norwood. Journ. Acad. Phila. iii, 17. 1854.
Productus æquicostatus, Shumard. Geol. Rep. Missouri, 201. 1855.
Productus cora, Marcou. Geol. N. A. Pl. VI. Fig. 4. 1858.
? *Productus lævicostus*, White. Journ. Bost. Soc. N. H., VII. 1860.
Productus Flemmgii, Geinitz. Carb.-format. u. Dyas in Nebraska, 52. 1866.
Productus Calhounianus, Geinitz (not Swallow) do. 1866.
Productus Konnickeanus, Geinitz, (not de Verneuil) 1860.
Productus Prattenianus, Meek. U. S. Geol. Surv. Net. 1872.
Productus Prattenianus White. Rep. U. S. Surv. 100 Mer. 1877. Also referred to in Ohio Geology as *P. aequicostatus*.

This is the most abundant species of productus in the Carboniferous of Licking county, making up almost the mass of the rock in many places, so that slabs may be secured whose entire surface is studded with the remains of this fossil. Yet, from the fragile character of the shell, it is rarely found not destroyed or broken. I transcribe Shumard's original description as a basis for the study of our forms.

"Shell large, broad, hinge-line equal to the greatest width of the shell. Dorsal valve much elevated, arched, visceral portion slightly flattened on the middle, sides falling rather abruptly to the ears. Ears large, triangular, with three or four broad folds, which are not continued across the visceral portion. Just within the cardinal border is a range of four or five small tubes on either side the beak. The beak is moderately obtuse, and passes a little beyond the cardinal border. The surface is covered with longitudinal rounded ribs, which, at from about one-fourth of the distance from the back, preserve nearly an uniform width to the front margin. Some of the ribs bifurcate near the beak, and then continue without further division, the spaces between them being occasionally supplied with new ones; they are nearly straight on the back of the shell, on the sides they are curved toward the lateral borders, and rendered flexuous by the folds. At ten lines from the beak there are fifteen ribs in the space of five lines, the whole number is from 150 to 160. The surface is studded with slender tubes, which in some specimens are separated from each other by pretty regular intervals, and arranged in oblique line across the shell; in others they are scattered promiscuously over the surface. Ventral valve concave, visceral portion nearly plane, subquadrilateral, with several folds which continue across the shell; these are prominent on the ears and side, but become obscure as they approach the middle.

Productus punctatus, Martin.

(Plate II, Fig. 29.)

This is also a widely distributed species which is not very common at Flint Ridge. Attaining a large size; shell thin, varying from subquadrate to longitudinally subovate, sometimes wider than long; hinge line always shorter than greatest width of valves; anterior outline regularly rounded or slightly sinnous in the middle. Ventral valve gibbous with a merial flattening or depression extending from the front nearly to the beak. Ears compressed, small (the specimen figured is distorted by pressure). Dorsal valve somewhat concave, with a slight medial prominence. Surface marked by regular, rather conspicuous, distant, concentric ridges, supporting numerous appressed spines. Length, 2.50, breadth, somewhat less.

Productus longispinus, Sowerby.

(Plate II, Figs. 25, 27, 28.)

This very common and characteristic shell is one of the most abundant fossils in the shales and limestones of the coal measures. Fig 25 illustrates the structure of the interior of the valve.

Productus muricatus, N. and P.

This form, often called a variety of the above, differs so constantly from P. longispinus as to be worthy of a distinct name. It is less common than the above and may be recognized by the fact that the striae are much coarser than in P. longispinus, and especially by the concentric wrinkles upon the dorsal part of the ventral valve, which inclines to become flattened in one plane.

Productus Nebrascensis, Owen.

(Plate II, Fig. 30.)

This widely distributed species is recognized by the peculiar nodulose character of the surface, the coarse radiating striae being crossed by irregular concentric ridges.

Productus costatus is very similar, as is *P. semireticulatus.*

Both last named species probably occur in these beds, but as the specimens do not now lie at command they are not enumerated.

Chonetes mesoloba.

Although not figured, this is one of the most abundant and characteristic fossils of the region and may be known by the prominent mesial fold. Its known vertical range in the county is over one hundred feet. A figure can be found in Dana's Manual p. 332.

Stricklandinia (?) *subquadrata*, sp. n.

(Plate I, Figs. 14, 14a.)

The generic reference is simply provisional, but the figures will illustrate the specific characters. One specimen is in the form of a cast showing some of the internal markings; these in some respects resemble Pentamerus. The general outline is almost exactly that of Lingula subquadrata of the Silurian, being subquadrate with parallel sides. The beaks are moderately prominent and the valves quite strongly convex. The shell is marked by rather strong distant striæ parallel to the edge. The interior of the ventral (?) valve (Fig. 14) is marked by two bifid grooves anteriorly and many pits. The largest specimen seen measures .70 by .50 inches.

Hemipronites crassus, M. and H.

(Plate II, Fig. 19.)

This common Orthis-like shell is common to the sub-carboniferous and coal measures but is much less common in the latter in Licking Co. Specimens of this species occur sparingly at Bald Hill and Flint Ridge.

PROTOZOA

Fusulina cylindrica, Fischer.

(Plate III, Fig. 20.)

The Foraminifera are represented by one species which is obtained from the flint-bearing limestone of Flint Ridge. In many places the rock was almost entirely composed of these minute shells not larger than and nearly the shape of a grain of wheat. The shell is not preserved but the cavity bears the markings of the exterior which are unmistakable. This seems to prove that the flint bearing limestone was formed at some depth and its flint must very likely be accounted for by supposing it to be derived from silicious protozoa and spongue spicules. Although this species probably had a calcareous shell it suggests that conditions prevailed suited to the growth of siliceous forms.

CORALS ETC.

A species of Zaphrentis (Plate II, Fig. 21.) is indicated by several poorly preserved specimens but these, as well as half a dozen species of Bryozoa, are reserved for a latter occasion. (See Appendix II.)

In conclusion we may remind the reader that this list is of necessity quite incomplete and hasty and that it has been prepared at a distance from means of accurate comparison with types and was designed to illustrate the richness of a single limited horizon and to prepare the way for the intelligent study of the difficult group of rocks below.

In fact, a larger number of species than are here described have been already figured from the Waverly and only a beginning is yet made. These plates it was hoped to print at this time but circumstances forbid. In the neighborhood of eighty-five species have been collected by the class from the coal measures during a few hasty trips to Flint Ridge. This is as many as have been described from the coal measures of Indiana. Meek, in the Ohio Paleontology describes only about twenty.

APPENDIX I. CARBONIFEROUS TRILOBITES.

It was intended to devote space to a somewhat extended discussion of the carboniferous Trilobites of America but lack of space and the incompleteness of the discussion possible at present has induced us to give up the idea, especially in view of the hint that a special work is soon to appear upon this subject. The following notes are, however, appended to the present paper in the hope that they may prove useful.

It is well known that during the carboniferous period trilobites rapidly approach extinction and but few remained to struggle with the adverse conditions of the Permian. But why the seas of the carboniferous were less favorable than those of the Cambrian and Silurian remains a mystery. Although the trilobite of the early Palæozoic was, perhaps, a synthetic type as argued by Agassiz, it would seem that the trilobites of the carboniferous belonged to a closed type with slight powers of adaption.

A careful study of the trilobites of the carboniferous rocks of America ought to throw some light on these matters if undertaken in a truly comparative spirit rather than from the standpoint of the mere systematist. Nevertheless it is necessary to first devote the requisite systematic study in order to give critical value to determinations. A review of the whole field is necessary, but its difficulty has been much lightened by the works of two European authors from which many of our statements are drawn. (*Valerian v. Moeller.* Ueber die Trilobiten der steinkohlen formation des Ural, nebst einer Uebersicht und einegen Ergaenzungen der bisherigen Beobachtungen ueber Kohlen Trilobiten, 1867; *H. Woodward.* A Monograph of the

British Carboniferous Trilobites 1883-81 Palaeontographical Society, London.)

The first description of trilobite remains from carboniferous rocks was that of the Abbe′ de Vitry in 1779. (3 Mem. de l'Acad. imper. et royale des sciences et belles lettres de Bruxelles, 1780.) Thirty years later William Martin described in his Petrificata Derbiensia a toilobite as *Entomolithus oniscites Derbyensis*, which he regarded as a petrified insect related to Oniscus.

In 1836, Phillips' Geology of Yorkshire appeared, in which eight species were described, albeit very imperfectly.

Portlock, in 1843, published his Geological Report on Londonderry in which for the first time the attempt was made to set up distinct genera for the carboniferous trilobites. *Phillipsia* and *Griffithides*, the two prominent genera, date from this report.

De Koninck added much to the general fund of information, although his studies were restricted to Belgium.

M'Coy's Synopsis of the characters of the carboniferous Limestone Fossils added several species although none too well distinguished.

FAMILY PROETIDÆ.

The four genera, Phillipsia, Griffithides, Brachymetopus, and Proetus, which constitute the family are all found in carboniferous rocks, while the first three are restricted to it, and Proetus begins in the Silurian. Phillipsia and Griffides really constitute one genus with two types more or less closely united. In both, the general form oval, the angles of the cheeks may be greatly produced, facial suture cutting obliquely across the posterior margin of the head shield; thoracic segments nine in number, pygidium with 12-18 segments, margin rounded, not fimbriated.

GENUS 1. PHILLIPSIA, Portlock, 1843

Glabella with nearly parallel sides, basal lobes, formed by a well defined furrow separating the posterior corners, distinct, middle glabella marked by two or more lateral furrows, eyes large, [illegible] cervical furrow deep.

GENUS 2. GRIFFITHIDES, Portlock, 1843

Glabella pyriform, tumid, destitute of lateral furrows, [illegible] small smooth, cervical lobe broad.

GENUS 3. PROETUS, Steininger, 1830.

General form oval, head short, pigidium longer; head-shield with a raised border and furrow; angle of free cheeks sometimes produced; basal lobes of glabella distinct, with or without lateral furrows; axial furrows distinct, facial suture diverging in front of eyes to form prominent palpebral lobes. Free thoracic segments 8-10. Pigidium with elevated axis, pluræ falling short of margin of the pigidium, which usually is smooth.

GENUS 4. BRACHYMETOPUS, M'Coy, 1847.

Head shield nearly semicircular, acutish in front, one-third wider than long; glabella small, about one-half length of head, with basal, but no lateral lobes; facial suture obscure; angles of cheeks produced; surface pustulate; pigidum with a rounded border, ribs with double furrows, surface ornamented.

The following list embraces all the now recognized species of carboniferous trilobites, so far as can be ascertained. It must be admitted that many species have been described in this country from fragments too imperfect or too incomplete to afford adequate means of comparison.

GENUS DALMANITES (?)

1. *D. cuyahogæ*, Claypole, (Plate II, Fig. 33.)

GENUS PROETES.

1. *P. laevis*, Woodward.
2. *P. auriculatis*, Hall.
3. *P. ellipticus*, Meek and Worthen.

GENUS PHILLIPSIA.

EUROPEAN SPECIES.

Known from heads and pigidia.

A. Angle of free cheek produced to form a long spine.

I. Axial lobe of glabella not expanded in front.

1. *P. gemmulifera*, Phillips. Two lateral furrows on the glabella, axis of pigidium, with about 18 somites. (Plate VI, 6.)

2. *P. truncatula*, Phillips. Three lateral furrows on glabella, axis of pigidium, wirh about 18 somites. (Plate VI, 7.)

II. Axial lobe of glabella expanded anteriorly.

(a) of medium size.

†. pigidium rather longer than wide.

3. *P. eichwaldi*, Fischer. Head nearly semi-circular, eyes large.

3a. *P. eichwaldi*, var. *mucronata*, McCoy. Pigidium, with a median posterior prominence. (Plate VI, 8.)

4. *P. leei*, Woodward. Eyes very small.

‡. pigidium broader than long.

5. *S. cliffordi*, Woodward. Pigidium twice as wide as long.

(b). Of small size.

6. *P. minor*, Woodward.

B. Angle of free cheeks not produced to form a conspicuous spine.

I. Anterior margin of glabella not expanded.

7. *P. derbiensis*, Martin, (Plate VI, Fig. 12.)

II. Anterior margin of glabella expanded.

a. Pigidium wider than long.

8. *P. colei*, McCoy, (Plate VI, Fig. 11.)

b. Pigidium longer than wide.

9. *P. scabra*, Woodward.

Known only from pigidia.

10. *P. articulosa*, Woodward. Resembles P. cliffordi, differing in having seventeen coalesced somites instead of thirteen.

11. *P carinata*, Salter. Axis of the tail acutely ridged, seventeen segments.

12. *P. laticaudata*, Woodward. Pigidium very wide, with twelve somites, axis elevated.

AMERICAN SPECIES.

Known from both heads and pigidia.

1. *P. swallovi*, Shumard.
2. *P. shumardi*, Herrick.
3. *P. sagamonensis*, Meek and Worthen.
4. *P. scitula*, Meek and Worthen.
5. *P. doris*, Winchell.
6. *P. rockfordensis*, Winchell.
7. *P. insignis*, Winchell.
8. *P. trinucleata*, Herrick.

own from pigidia or glabellæ only.
9. *P. meramecensis*, Shumard.
10. *P. missouriensis*, Shumard.
11. *P. major*, Shumard.
12. *P. cliftonensis*, Shumard.
(?)13. *P. stevensoni*, Meek.
14. *P. peranulata*, Shumard.
(?)15. *P. latispinosa*, Sandberger.
(?)16. *P. tennesseensis*, Winchell.

Genus Griffithides.

1. *G. acanthiceps*, Woodward, (Plate VI, Fig. 10.)
2, *G. brevispinus*, Woodward.
3. *G. calcaratus*, McCoy, (Plate VI, Fig. 16.*)
[*Figure omitted in plate, it lies above and between 11 and 12.]
(?)4. *G*, *carringtonensis*, Etheridge.
5. *G. glaber*, Woodward.
6. *G. globiceps*, Phillips.
7. *G. longispinus*, Portlock.
8. *G. moriceps*, Woodward.
9. *G. obsoletus*, Phillips.
10. *G. platyceps*, Portlock.
11. *G.*, *seminiferus*, Phhillips.
12. *G. roemeri*, Moeller.
13. *G. gruenewaldti*, Moeller.
14. *G. bufo*, Meek and Worthen.
15. *G. portlocki*, Meek and Worthen.
16. *G. longiceps*, Portlock.

Genus Brachymetopus.

1. *B. discors*, McCoy.
2. *B. hibernicus*, Woodward.
3. *B. McCoyi*, Portlock, (Plate VI, Fig. 16.)
4. *B. ouralicus*, McCoy, (Plate VI, Fig. 14.)
(?)5. *B. lodiensis*, Meek, (Plate III, Fig. 4.)

Annotations on the above list.

Dalmanites ? cuyahogæ Claypole was described in the Geol. Mag., Decade iii. vol. i, p. 306, 1883. The specimen described was a nearly entire pigidium, differing from all known carboniferous species in the long spinous processes, which resemble those of Dalmanites.

It might be observed that the great size of the median lobe is suggestive that possibly the marginal part of the pigidium had been somehow removed, leaving the ribs irregularly preserved. The pigidium might then belong to *Brachymetopus*, but such a mutilation would most assuredly have been noticed by Prof. Claypole.

The specimens referred to *Proetus* consist of pigidia and fragments and the reference is based on analogy simply.

Of the species of *Phulipsia* figured, it is not necessary to give descriptions, while condensed descriptions of the others, as far as they can now be drawn up, are given.

The various authorities who have described *P. æqualis* (— P. posthumus.) disagree even in essential characteristics, so that for the present its position must remain doubtful.

P. articulosa is closely related to *P. cliffordi*, from which it differs in the greater number of coalesced somites.

"Pigidium [the only part known] one-fourth broader than long, axis one-third breadth, consisting of seventeen coalesced segments, which diminish rapidly in breadth to the extremity, which is bluntly round, and less than one third the breadth of the axis at the [illegible] end; axial furrows deeply marked. Pleurae 13, terminating [illegible] within the margin, which is finely striated, unornamented."

P. [illegible], is too imperfect in the specimens as yet [illegible] to be worthy of description.

P. [illegible] Pigidium twice as long as broad, axis one [illegible] breadth at proximal border, rapidly diminishing to one seve[illegible] border is posteriorly one seventh the length of the pigidium, [illegible] minishes laterally; axis of 13 somites, with [illegible] lateral [illegible] bifurcate as they approach the margin, unornamented.

P. laticaudata. Pigidium much broader than long, very [illegible] trilobed; axis elevated, consisting of 12 somites, each [illegible] and ornamented with a series of minute tubercles. Pleurae [illegible] for [illegible] length, minutely ornamented, losing themselves [illegible] margin [illegible] length [illegible] breadth [illegible]

Our restoration of the head of *P.* [illegible] from [illegible] specimens and hence may not be accurate in every part. [illegible] broader than long; the axis forms [illegible] of its breadth at the proximal border, but diminishes very rapidly, terminating in a somewhat blunt point near the posterior margin, About 14 somites, with about 9 pluræ, surrounded by a narrow, smooth border. The pigidium is more triangular that of *P. colei.*

P. minor is a very small species, having a pigidium resembling that of *P. eichwaldi.* Head shield rounded in front, one-third broader than long; glabella occupying one-third breadth, oval, slightly broader in front, tumid, with distinctly marked basal lobes; lateral furrow indistinct; neck-lobe rather prominent; angle of cheek produced into a short slightly curved spine.

P. quadrilimba is too imperfectly described to be recognized and might better be dropped from synonomy.

Griffithides brevispinus is known only from two fragments of the head. The author describes as follows:

"Head nearly twice as broad as long; free cheek, terminating laterally in a short spine; the eye, which is very smooth, is rounder and more tumid than in other species. The glabella is nearly smooth in front, and overhangs the anterior border of head-shield; posterior portion of the glabella and the neck-lobe irregularly tuberculated; free cheek also tuberculated, about 8 tubercles on each cheek, placed in a semicircle about the eyes. Margin of shield raised and striated."

G. ? carringtonensis is represented by pigidia resembling very much that of *G. obsoletus*, except that this species has 12 axial segments and has a distinct margin to the pigidium, while *G. obsoletus* has but 10 segments.

G. obsoletus. Pigidium one-fourth broader than long, composed of 10 segments, oxis much broader than plural portion; each of the 9 rib-like plicæ marked by a furrow down the centre, margin smooth. Glabella covered with peculiar striations.

G. platyceps was described from a fragmentary glabella, only and is not recognizable.

The two species of *Brachymetopus*, *B. discors* and *B. hibernicus* are founded on pigidia only and the outline drawings given will afford all the information we possess concerning them.

Meek's *Philllpsia lodiensis*, if a Brachymetopus, is the only member of this genus yet found in America.

We have thus hastily reviewed the exotic species and turn to a more careful study of the American forms. In the first place, let us examine the original descriptions.

GENUS PHILLIPSIA.

Phillipsia swallovi, Shumard.

Proetus swallovi, Shumard. Geol. Surv. Missouri.

"Head semi-circular, swollen, exterior border narrow, slightly elevated and marked with 4 or 5 thread-like striæ; sinus of the border shallow and indistinct; posterior border of cheeks rather wide, and limted internally by a shallow, but distinct groove; genal angle short and round?; glabella tumid, elevated above the plane of the cheeks; occupying about four-fifths the entire length of head, rather more than half as wide as long; front rounded; sides convex in advance of the eyes; slightly concave in the middle, and expanding again posteriorly; lobation indistinctly marked by three very shallow depressions on each side, the anterior and middle ones being nearly obsolete; occipital segment wider than the base of the glabella; occipital furrow slightly arched toward the front, narrow, rather deeply impressed, widest at the extremities; the furrow which separates the glabella from the cheeks [facial suture] is narrow, flexuous and slightly impressed; palpebraral lobes semi-oval, visual surfaces minutely reticulated. Thorax with 9 segments; axial lobe elevated, width greater than lateral lobes [pleural portions], rings rather wide, flattened in the direction of the axis; pigidium parabolic, moderately convex; length about equal to head; border rather wide; axial lobe elevated, as wide as lateral lobes; segments eleven, lateral lobes about seven, indistinct. Whole surface minutely punctuate; the punctures sometimes disposed in quincunx, and sometimes irregularly. Length of head, 3½ lines; greatest width, 6 lines."

The species is described from the Chemung, at Chouteau Springs, Cooper Co., Missouri, but it is suspected that the formation will be found to be really subcarboniferous.

Phillipsia shumardi, Herrick.

Proetus missouriensis, Shum. Geol. Surv. Missouri.

Glabella tumid, greatest height about the centre, ovoid, obtusely rounded in front, truncated posteriorly, length a little greater than width, widest behind, three furrows on either side, posterior pair strongly marked, these commence at the dorsal sinus about one third from base to front, pass in a curve backward, and bifurcate about midway between the sides and middle of the glabella, one branch very short, is continued for a short distance almost transversely, the other bends back nearly to occipital sinus and, with the main branch, partially encloses a large oval lobe on either side, the lobes [basal lobes] separated by a space about one-half width of glabella; middle pair of furrows shallow, curving backwards in a direction nearly parallel with the posterior ones, but considerably shorter, anterior pair feebly impressed, a little oblique; occipital sinus a little convex toward the front, shallowest in the middle; occipital ring [neck-lobe] wide, flattened, much lower than the plane of glabella. Pigidium semicircular, flattened convex, width double the length, margin broad and slightly concave; axial lobe almost as wide as the lateral lobes, rounded at the extremity, segments 10, separated by well-marked furrows; surface thickly studded with granulæ, which are rather smaller than those of the glabella. Length of head, 8½ lines; greatest width, 7½ lines; length of pigidium, 6½ lines; width 1 inch.

This species is also described from the Lithographic limestone said to be of Chemung age, but it occurs to in the Waverly (subcarboniferous) of Ohio, at Granville. As this species is certainly a Phillipsia the name was preoccupied by *Phillipsia missouriensis*, Shumard, from Middle Coal Measnres at Lexington, Mo., described in 1858, Trans. Acad. Sci., St. Louis.

Phillipsia meramecensis, Shumard.

"Pigidium [only portion known] semi-elliptical, rather wider than long, very convex; border moderately narrow; axial lobe not quite as wide as the lateral lobes, and considerably elevated above them; anterior extremity arched; posterior extremity obtusely rounded; rings 13. convex on the dorsum, but shallow and narrow on the flattened sides; lateral lobes strongly arched downward; ribs about 12, indistinct, except the last two or three; the first four from the thoracic margin marked by a shallow, but distinct furrow, which is situated very near the posterior edge; furrows between the ribs rather deeply impressed. Surface very finely granulose. Length, six lines; width, 6½ lines."

Described from the so-called Archimedes limestone, in St. Louis Co., Mo. There is nothing characteristic about the pigidium described, though it may be readily distinguished from the previous one.

Phillipsia missouriensis, Shumard.

Pigidium semi-elliptical, elevated, width greater than length; surface very finely punctate, punctæ rather distant and arranged what in quincunx; margin rather broad and smooth; axial lobe str arched transversely, gradually tapering, forming not quite fou the total length; its width equal to about three-fourths the wi lateral lobe; rings about 18, rounded on the dorsum and flatten the extremities, transverse furrow narrow, distinctly impressed o dorsum, becoming obsolete before reaching the longitudinal fur lateral lobes rather strongly arched transversely; anterior margi gulated, apex of angle elevated and situated nearest the axial segments eleven, rounded, curving slightly downwards, not furr furrows between the segments rather deeply impressed, except tl posterior ones, which are quite shallow. Length, .68; width length of axial lobe, .56; width, .23.

Such a description of a pigidium simply can have but a value.

Phillipsia major, Shumard.

Pigidium [only part known] large, elevated, approaching to elliptical, a little wider than long; surface smooth, or very punctuate; outline of edges sinuate, margin broad, particular ward the posterior extremity; axial lobe very much elevated, tapering, forming five-sixths of the total length, not so wide as tl eral lobe, rather strongly arched longitudinally, sides with a shallow groove running their whole length; rings 23, very str arched from side to side to side, angulated in the lateral depre and their extremities directed obliquely backward. The first from the front are very flat in a longitudinal direction, and are rated from each other by fine, scarcely impressed, transverse lin furrows. Posterior to these the furrows are distinctly impressed extremity of the lobe, while the rings become gradually more ro on the dorsum, but on the sides they still continue flattened. L lobes moderately convex, obtusely angulated in front; segmen rounded, slightly sinuate, simple; furrows rather strongly impr except the two last, which are nearly obsolete. Width, 1.2 length, 1.10; length of axial lobe, .93; width at anterior extremity,

This very large species has several peculiarities which may it possible to recognize it from the description. It is said to hav derived from the upper coal measures in Kansas.

Meek was apparently in error in identifying the specimens fi in his Paleontology of Nebraska, with Shumard's P. major. The former are characterized by a rather unusual length of pigidia, while those of the latter are broad. The pigidium Fig. 1, Plate II, of the Nebraska report closely resembles Griffithides obsoletus.

Phillipsia cliftonensis, Shumard.

Pigidium small, semi-elliptical, gibbous, width greater than the length; axial lobe elevated longitudinaliy, gently arched, dorsum slightly depressed, width at forward extremity about equal to one lateral lobe exclusive of smooth margin, gradually tapering and terminating in a blunt point posteriorly; rings from 13 to 14, sub-granulose, separated by distinctly impressed furrows; lateral lobes angulated near the middle, flattened above and on the sides, well defined from the margin by a shallow, but distinct furrow; segments 7, rounded, separated by distinct linear sulci; margin moderately wide and regularly convex. Length, .23; width, .25; heigt, .11; height of axial lobe, .04; length, .19.

This is also from the upper coal measures of Kansas.

Phillipsia sangamonsis. Meek and Worthen.

(Plate V, Fig. 13.)

Sub-ovate; cephalic shield convex, regularly rounded in front, cheeks produced into carinated processes less than one-third entire median length ef head; glabella convex, sub-inflated, axial suture moderately well defined, greatest convexity behind the middle, length 1¼ width, sides nearly parallel; posterior lobes large, prominent; second lateral furrow curved, oblique, anterior furrows nearly obsolete; cervical segment and suture well defined; facial suture quite well defined, intersecting posterior margin midway to angle. Eyes rather large, half as long as glabella, exclusive of cervical segment, prominent; palpebral lobes convex, resting upon the eye like a lid.

Pigidium semi-elliptical, rather convex, a little wider than long, narrow and rather longer than head, narrowing posteriorly, abruptly rounded behind; mesial lobe prominent, a little flattened at each side, narrower than the lateral lobes, from which it is separated by a broad furrow, about two-thirds entire length of glabella; lateral lobes less prominent, abruptly convex at outer side; segments 9 or 10, all terminating abruptly at the edge of a broad marginal zone, which is widest posteriorly; surface smooth. Length of head, medianly, .50; breadth, .65; length of glabella, .35; width, .30.

This species is said to be rather common in the Western states, but it has not yet been secured from Ohio.

Phillipsia scitula, Meek and Worthen.

Elliptical; head semi-elliptical, tumid, one-third wider than long, anterior margin rounded, cheeks produced into spines extending to fifth thoracic segment; glabella broadly rounded, occupying the margin in front, most elevated posteriorly, axial sutures obsolete anteriorly, posterior lateral lobes rather large, very oblique, lateral lobes almost obsolete: cervical segment more prominent than the glabella, with a median tubercle, cervical suture deep; eyes one-half as long as the glabella; palpebral lobes semi circular, convex; cheeks small; pigidium almost as long as head, narrower, mesial lobe prominent, wider than lateral lobes, border wide; surface granular. Entire length, .70; pigidium, .20; width of pigidium, .30; length of head, .25; width, .31.

Judging from the figures and descriptions this species is the nearest approach to Griffithides yet found in America. The presence of lateral furrows on the glabella indicate a member of Phillipsia, however, as the genera are now understood.

Phillipsia doris, Hall's Winchell.

Head surrounded by an outwardly inclined border marked [illegible] a deep groove from the cheeks, which are produced into spines [illegible] nearly one third whole length of head shield; glabella prolate [illegible] elliptical, with large postero-lateral lobes, the lateral furrows [illegible] pigidium semi-elliptical, axial portion convex, diminishing to an [illegible] point; lateral lobes somewhat narrower, bordered by a smooth marginal area, axis with 11 articulations, lateral lobe 7, surface of [illegible] granulose.

Winchell says, also "middle of the border (of head) marked [illegible] a groove which reaches a point opposite one eye, to the corresponding point on the other side of the head," which seems somewhat difficult to understand. The species was obtained from Rockford, Indiana. Width of pigidium, .55; length, .21.

Phillipsia rockfordensis, Winchell

"Cephalic shield surrounded by a narrow, convex border, [illegible] is bounded internally by a narrow, but deep groove, and terminates posteriorly in conically tapering genal points. The principal lobe of the glabella is relatively very large, convex, highest in the middle, widened anteriorly, circularly rounded in front, and gently curved on the sides; no glabellar furrows are present. The complimentary [postero lateral] lobes are large, oval, and project laterally farther than the main lobe. The surface of glabella finely, but sharply granulated; margin finely striated. Size about as that of *P. doris*. Collected at Rockford, Indiana."

P. insignis, Winchell, is closely allied to *P. meramecensis*, Shumard. Not having access to the original description I can only gather that the head is armed with spines "which reach twice the length of the glabella from the anterior end," and the eyes are large, while the pigidium has a plane margin.

P. howi, was described by Mr. Billings. It is said to be closely allied to the above, but has a greater number of annuli in the axis of the pigidium, which alone is known.

P. vindobonensis, Hartt, is described as follows:

"Pigidium semi-elliptical, very convex; (one or two segments appear to be wanting from the anterior margin of the only specimen seen,) but its width must have been greater than its length. Ten or eleven articulations are visible on the side lobes and twelve of the axis, which is very prominent and moderately tapering. The axial rings are depressed, convex, becoming smaller, more crowded, and more distant toward the apex. Ribs on the side lobes depressed, convex, decreasing in length, breadth and distinctness from before backward, while at the same time they become more and more inclined backward. The six anterior ribs preserved show a distinctly marked groove, originating on the posterior margin at about one-third the length of the rib from the axis, and running obliquely, increasing in depth to the end of the rib. Smooth border none, or extremely narrow at the anterior angles, but becoming three-fifths the width of the axis near the posterior part of the pigidium, which is not visible in the only specimen I have examined."

We have here, therefore, a species described from a fragment of a pigidium, exhibiting neither end and nothing else of importance, an example of puerility too often followed.

Phillipsia, trinucleata, n. sp.

A considerable number of specimens have been collected which were at first supposed to be *P. sangamonensis*, but are evidently quite distinct from any described species. It is not absolutely certain that the cheek spine belongs to the same species as the glabella and pigidia with which it was associated, yet the circumstances render it highly probable.

The glabella presents the most distinctive features. It is considerably longer than wide and quite convex, the greatest height being posterior to the middle. Anterior depressed margin rather narrow in front, expanded laterally; sides nearly straight or somewhat concave near the eyes; postero-lateral lobes very sharply defined, conical, oblique, with a second smaller pair in front of them, and a very faintly outlined second pair still farther forward; between the postero-lateral lobes a sharply defined, prominent, median elevation, almost as large as the others; cervical segment convex, high, often with a single median tubercle. The surface of the glabella is minutely ornamented and on either side in front of the eyes is an oval pit which has been thought by some to represent the insertion of the antenna or organ of sense.

The eyes are large and supported by a prominent palpebral lobe. A single movable cheek has been found. The margin is obliquely inclined, forming a prominent angle at its union with the face; middle of cheek depressed and marked with an impressed line; cheek produced into a spine as long as the whole remainder of the cheek length of cheek, .77 (the spine, .35); length of eye, .11. Pigidia are not rare and are very convex, the median lobe especially being convex from side to side and particularly prominent posteriorly. The median lobe occupies one-third or less the width of the pigidium proximally and tapers gradually, forming a portion of a regular truncated cone; on either side an impressed line marking off an accessory portion; axial segments 17-19; lateral lobes convex; pluræ flattened slightly above, separated by very deep sutures; margin broad, longitudinally striate, abruptly deflexed; ribs 9-12. Length of pigidium .35; width, .45, length of axial lobe, .27. Another individual, length .48, width, .56, axial lobe, width, .20, length, 40. The pigidium is generally, if not always ornamented by minute pistules on the summits of the segments which are borne on the top of a slightly elevated, flattened ridge forming the axis of the annuli.

PLATE I.

(Figures, unless otherwise indicated, natural size.)

Fig. 1. Entolium aviculatum, *Swallow*, left valve.
Fig. 2. Right valve of the same—p. 23.
Fig. 3. Aviculopecten ?
Fig. 4. Aviculopecten coxanus, *M. and W.*
Fig. 5. Aviculopecten hertzeri, *Meek*, or related species—p. 25.
Fig. 6. Aviculopecten sp?—p. 27.
Fig. 8. Aviculopecten scalaris, *Herrick*—p. 26.
Fig. 9.
Fig. 10. Aviculopecten hertzeri, *Meek*—p. 25.
Lig. 11. Entolium attenuatum, *Herrick*—p. 24.
Fig. 12. Martinia planoconvexa, *Sch*—p. 46.
Fig. 13. a, b, c. Martinia lineata, *Martin*—p. 46.
Fig. 14. Stricklandia? subquadrata, *Herrick*—p. 49.
Fig. 16. a, b, c. Athyris subtilita ??—cf. Pal. Neb. Plate I, ig. 12.
Fig. 17. Aviculopecten coxanus, *M. and W.*—p. 26.
Fig. 18. Athyris subtilita, *Hall*—p. 44.
Fig. 19. Solen sp.—p. 38.
Fig. 20. Aviculopinna americana, *Meek*—p. 38.
Fig. 21. Ostracode crustacean ? a single valve.
Fig. 22. Allorisma sp?
Fig. 23. Phillipsia trinucleata, *Herrick*.
Fig. 24. Productus sp. Small individual.

PLATE II.

Fig. 1. Bellerophon montfortianus, *N. and P.*—p. 19.
Fig. 2. Macrocheilus planus?—p. 21.
Fig. 3.
Fig. 4 and 5. Euomphalus sp.—p. 22.
Fig. 6. Spirifer sp.
Fig. 7. Bellerophon subcordiformis, *Herrick*—p. 18.
Fig. 8. Discina Meekana, *Whitfield*, with shell partly preserved.
Fig. 9. Under valve of same ?
Fig. 10. Orbiculoidea? sp. Incorrectly drawn, the outline is not circular, but somewhat elliptical. Very likely the same species figured

but not named by Meek, in Paleontology of Nebraska, Plate IV, Fig – 3.

Figs, 11 and 13. Pleurotomaria sp.
Fig. 12. Bellerophon decussatus, *Fleming?*—p. 19.
Fig. 14. Bellerophon percarinatus, *Con:*—p. 17.
Fig. 15. Polyphemopsis inornata, *M. and W.*—p. 20.
Fig. 16. Macrocheilus medialis, *M. and W.*—p. 21.
Fig. 17. Nautilus sp.—p. 17.
Fig. 18. Pleurotomaria newportensis, *White*—p. 21.
Fig. 19. Hemiphronites crassus, *M. and H.*—p. 50.
Fig. 20. Bellerophon carbonarius, *Cox*—p. 10.
Fig. 21. Zaphrentis, sp.
Fig. 22. Spirifer camerata, *Morton*—p. 45.
Fig. 23. Spirifer opima, *Hall*—p. 44.
Fig. 24. Spirifer striata?
Figs. 25, 27, 28. Productus longispinus, *Sowerby*—p. 48.
Fig. 26. Productus cora, *Owen*—p. 47.
Fig. 29. Productus punctatus, *Martin*—p. 48.
Fig. 30. Productus nebrascensis. *Owen*—p. 49.
Fig. 31. Productus sp.
Fig. 32. Phillipsia trinucleata, *Herrick*, decorticated glabella.
Fig. 33. Dalmanites? cuyahogæ, *Claypole*, pigidium.
Fig. 34. Unidentified gasteropod.

PLATE III.

Fig. 1. Macrocheilus sp?
Fig. 2. Loxonema sp.
Fig. 3. Bellerophon nodocarinatus, *Hall*—p. 18.
Fig. 4. Brachymetopsus lodiensis, *Meek.*
Fig. 5. Griffithides glaber, *Woodw.*—restored.
Fig. 6. Phillipsia scabra, *Woodw.*
Fig. 7. Allorisma costata, *M. and W.*—p. 33.
Fig. 8. Solenomya subradiata, *Herrick*—p. 30.
Fig. 9. Crenipecten foerstii, *Herrick*, both valves of the same shell

Fig. 9a. (near the centre of the plate) cast of same with impression of hinge line.

Fig. 10. Outline of Entolium aviculatum as found at Flint Ridge. Two valves in position, showing supposed relation.

Fig. 11. Clinopistha radiata, *Hall*—p. 34.
Fig. 12. Gervillia (Avicula) ohioense, *Herrick*—p. 36.

Fig. 13. Aviculopecten carboniferus. (Accidentally omitted from list.)
Fig. 14. Schizodus (?) spellmani, *Herrick*—p. 42.
Fig. 15. Schizodus wheeleri, *Swallow*—p. 42.
Fig. 16. Aviculopecten sorer, *Herrick*—p. 27.
Fig. 17. Edmondia sp?—p. 38.
Fig. 18. Aviculopecten?—p. 25.
Fig. 19. Discina convexa, *Shum*, (*?*) Omitted from list.
Fig. 20. Aviculopecten sp?—above No. 19.
Fig. 21. Phillipsia trinucleata, *Herrick*.

PLATE IV.

Fig. 1, 2. Allorisma subcuneata, *M. and H.*—p. 35.
Figr 3. Prothyris elegans, *Meek*—p. 38.
Fig. 6. Myalina swallovi, *McChesney*—p. 37.
Fig. 7.
Fig. 8.
Fig. 9. Solenomya? meekana, *Herrick*—p. 30.
Fig. 10. Solenomya anodontoides, *Meek*—p. 29.
Fig. 11. Placunopsis recticardinalis, *Meek*—p 43.
Fig. 12. Myalina?
Fig. 13. Gervillia (Avicula) ohioense, *Herrick*—p. 36.
Fig. 14. Macrodon carbonaria, *Cox?*—p. 32.
Fig. 15. Pleurophorus tropidophorus, *Meek*—p. 35.
Fig. 16. Pleurophorus subcostatus, *M. and W.*—p. 35.
Figs. 17, 18. Cypricardina carbonaria, *Meek*—p. 35.
Fig. 19. Macrodon obsoletus, *Meek*—p. 31.
Fig. 20. Myalina sp.
Fig. 21. Macrodon carbonaria, *Cox*—p. 32.
Fig. 22. Schizodus affinis, *Herrick*.
Fig. 23. Schizodus cuneatus, *Meek ?*--p. 32.
Fig. 24. Schizodus subcircularis, *Herrick*.
Fig. 25. Lima retifera, *Shumard*—p. 29.
Fig. 26. Nuculana bellistriata, *Stevens*—p. 40.
Fig. 27. Allorisma geinitzi, *Meek*—p. 53,
Fig, 28. Allorisma costata. *M. and W.*—p. 33.
Fig. 30. (Specimen mislaid.)
Fig. 31. Astartella varica, *McChesney*—p. 39.
Fig. 32. Microdon subelliptica, *Hall*—p. 40.
Fig. 33. Astartella newberryi, *Meek*—p. 39.
Fig. 34. Unidentified.

PLATE V.

Fig. 1. Allorisma?
Fig. 2. Orthoceras cribrosum, *Geinitz*—p. 17.
Fig. 3. Lima retifera, *Shumard*—p. 29.
Fig. 4. Myalina subquadrata? (cf. M. recurvirostra.)
Fig. 5. Euomphalus sp—p. 22.
Fig. 6. Bellerophon crassus, *M. and W.*—p. 22.
Fig. 7. Bellerophon marcouianus, *Geinitz*—p. 20.
Fig. 8. Bellerophon montfortianus, *N. and P.*—p. 19.

Figs. 9 and 10. Outlines of large plates, apparently part of h[illegible]ad armor of fishes, one-half natural size.

Fig. 11. Phillipsia swallovi, *Shumard.*
Fig. 12. Phillipsia leei, *Woodw.*
Fig. 13. Phillipsia sangamonensis, *M. and W.* head.

PLATE VI.

Fig. 1. Griffithides globiceps, *Phillips.*
Fig. 2. Griffithides longispinus, *Portlock.*
Fig. 3. Griffithides longisceps, *Portlock.*
Fig. 4. Griffithides seminiferus, *Phillips.*
Fig. 5. Griffithides moriceps, *Woodward.*
Fig. 6. Phillipsia gemmulifera, *Phillips.*
Fig. 7. Phillipsia truncatula, *Phillips.*
Fig. 8. Phillipsia eichwaldi, var. mucronata, *McCoy.*
Fig. 10. Griffithides acanthiceps, *Woodward.*
Fig. 11. Phillipsia colei, *McCoy*, 11a, hypostome.
Fig. 12. Phillipsia derbiensis, *Martin.*
Fig. 13. Griffithides roemeri, *Moeller.*
Fig. 14. Brachymetopus ouralicus, *De Verneail.*
Fig. 15. Griffithides gruenewaldti, *Moeller.*
Fig. 16. Brachymetopus maccoyi, *Portlock.*
Fig. 17. Griffithides calcaratus, *McCoy.*

These figures are mostly reduced from Woodward's monograph with slight modifications.

Since the preceding synopsis of Trilobites was put in type, a fine specimen of Phillipsia shumardi, (missouriensis, Shumard,) was found in the Waverly, south of Granville, by W. F. Cooper, which makes it possible for us to complete the description quoted on page 58, and to correct a few minor inaccuracies. This identification, which can hardly be open to the slightest question, will throw additional light on the position of the Lithographic limestone of Missouri.

Phillipsia shumardi, Herrick.

(Plate VII, Fig. 14.)

Proetus missouriensis, Shum., Geol. Surv. Missouri, p. 196. (See ante, p. 58.)

The description following is based upon an entire and nearly perfect specimen from the Waverly freestone at Granville, O.:

General form elongate, oblong elliptical, axial portions strongly elevated; outline of head somewhat parabolic, nearly twice as broad as axial length. Head shield very high axially, the height of the glabella being considerably more than one-fourth the entire width of the head shield; cheeks produced into spines reaching about to the third thoracic segment. The glabella is short and broadly rounded anteriorly, margin in front thickened to form a high mural ridge or lip separated from the prominent frontal portion by a deep sulcus; axial portion about one-third as wide as the entire head shield and scarcely expanded anteriorly, marked by three lateral sulci. The basal (posterolateral) lobes are large and oblique, separated by an interval equalling about half the width of glabella. The sulcus anterior to the lobes has a slight tendency to bifurcate and the two in front of it are faint and less oblique. The palpebral lobes are very large. The cervical groove is deep and abrupt and the cervical segment does not rise to the level of the median axial portion. The cheeks are extensive and decline greatly to a submarginal groove. The spine is of moderate length and the margin is greatly rounded and exhibits (sub-epidermal?) striations. The eyes are unfortunately destroyed in all specimens seen, but evidently were large. The suture separating the fixed cheeks is also obliterated, but its position is approximately indicated in our figure.

The thorax consists of ten distinctly separated segments. The axial portion is high and evenly convex and the lateral portions are rather abruptly flexed near the middle of their width and the pluræ are high and convex, not sulcate. The pigidium is one third wider than long (Shumard's specimen was a fragment) and the postero-lateral outline is a perfect arc of a circle, whose centre lies axially about four-fifths its length from the posterior extremity of the pigidium. The axial portion is high and tumidly conical and rather obtuse, the marginal sulci being rather deep. The pleural portions are convex and descend rapidly peripherally to the plane of the wide, convex, smooth border which is unmarked or ornamented with concentric striations. The axial segments are ten or eleven and are not sulcate, while the eight or nine pleural ribs are distant and prominent and bifurcate toward the outer end. Entire length, 1.80; width, 1.00; axial length of head, .50; entire length, .85; length of pigidium, .70; width of pigidium, 1.00; width of axial lobe of pigidium, .35; width of axial lobe of thorax anteriorly, .40.

Shumard's statement that the margin of the pigidium is concave, was due to the exfoliation of that portion of the specimen. Several of our specimens are in the same state of preservation.

NOTE.—*Phillipsia elliptica*, M. and W. which, by a curious oversight, was omitted from our list, is much more like P. swallovi than the present species. Refer to Pal. Ill., vol. III, p. 460; Plate [illegible]4, Fig. 8.

APPENDIX III. FLINT RIDGE BRYOZOA.

BY A. F. FOERSTE.

The following bryozoa, from Flint Ridge and the equivalent strata at Bald Hill, are the result of several days' collecting at each locality. Considering the wealth of bryozoa in the Carboniferous formations of America, the literature is scanty and frequently very unsatisfactory. Hiram A. Prout described about thirty-five species in the Trans. St. Louis Acad. Sci., from 1858 to 1860. James Hall described about eight species, in the Proc. Am. Ass'n. Adv. Sci. in 1857, and three species in the Geo. Rep. of Iowa, in 1858. F. B. Meek, alone and in conjunction with Worthen, published about nine species. Rominger, Dawson, Geinitz, White, Nicholson, and Swallow have each added one or more species at various times. To these, E. O. Ulrich has added about eighteen species in his American Paleozoic Bryozoa, published from 1882 to 1884. To these publications of Mr. Ulrich I am greatly indebted, as will appear throughout the following notes. Until some of the species published by Prout and others are better understood, the work on Carboniferous bryozoa will remain rather unsatisfactory. It is hoped that the following notes will at least not further involve this subject.

RHABDOMESONTIDÆ, Vine.

Ramose bryozoa; cells radiating in all directions from the central axis, of one kind only, tubular, with an expanded aperture, and an angular immature region.

GENUS RHOMBOPORA, Meek.

Branches slender; cells radiating from an imaginary central axis; aperture oval, placed at the bottom of concave, rhomboidal or hexagonal "vestibules," the latter separated by spines, frequently arranged in one or more rows along the dividing ridges.

I. RHOMBOPORA MULTIPORA, *sp. n.*

(*Plate* VII, *Fig.* 1, *a*, *b*, *c*.)

Branches doubtlessly dividing; in a length of 25 mm. no such division has taken place, but traces in the rock about 10 mm. beyond seem to indicate that some method of branching has occurred. Branches of medium size, 1.4 mm. wide. Cells arranged in diagonal intersecting and in longitudinal rows; at least 7 cells are found in a distance of 2 mm. in the vertical rows, and about 9 cells in the same distance in the diagonal series. About 20 longitudinal rows surround the stem. Mature region of the cells short, strongly deflected laterally, but not reaching the surface at right angles to the same; immature region much longer, departing from the centre of the branch at a low angle, suddenly bending into the mature portion. The vestibule in well preserved regions has sloping sides and an hexagonal oval outline; the ridges separating the cells are rather narrow and are covered with low, indistinct closely arranged granules, which do not seem to be arranged in well defined rows, as in other species of this genus; in worn portions of the specimen the ridges seem broader and lower, and the granules are indistinct, and scattered. Towards the base the vestibule is more inclined, lengthening its outline; at or [illegible] within its border there is frequently a low, rounded node, easily [illegible] looked.

From most species of this genus this form may be readily [illegible]guished by the size of the branches and the more numerous cells. [illegible] *lepidodendroides*, *Meek*, has branches 1.75 to 3 mm. wide, from [illegible] 6.5 cells occupy the oblique rows [illegible] standard length. *Rh. crassa*, *Ulrich*, has branches 2.5 to 3.5 mm. wide, from [illegible] cells occupy the oblique rows. *Rh. persimilis*, *Ulrich*, has [illegible] .88 mm. wide, 4.4 cells occupy the vertical rows, and 8 cells [illegible]lique rows. *Rh. pulchella*, *Ulrich*, has the same measurements [illegible] last. *Rh. armata*, *Ulrich*, has branches perhaps slightly w[illegible] the last two, about 5.5 cells occupy the vertical rows, and 9.5 [illegible] oblique rows. *Rh. elegantula*, *Ulrich*, has branches .25 mm. [illegible] from 3 to 4 cells occupy the vertical rows, and almost 5 cells [illegible]agonal rows. *Rh. Wortheni*, *Ulrich*, has branches from 1.3 to 2 [illegible] wide, 6 cells occupy the vertical rows, and almost 9 cells the [illegible] rows.

I[illegible] nearest ally of this species in external features seems [illegible]

Rh. lepidodendroidea, Meek. From this it may be distinguished by the following characteristics. The mature region of the cells appears more abruptly inclined to the immature region of the cells; the ridges between the cells are covered with smaller and more numerous granules, these are also present on the slopes of the vestibules, and are not arranged in such well defined rows as in the other species. Meek in his description of the type specimens gives the following measurements: number of cells in .2 inch, measuring longitudinally, 12; number of cells in .05 inch measuring in the direction of the oblique rows, 4. We have specimens from Kansas City which agree very well with these measurements. The Ohio specimens on the other hand present the following measurements: number of cells in .2 inch, measuring longitudinally, 17; number of cells in .05 inch, measuring in the direction of the oblique rows, 6.

Rare at Flint Ridge. (*Multipora* many pores or cells.)

II. RHOMBOPORA LEPIDODENDROIDEA, *Meek.*

(*Plate* VII, *Fig.* 3 *a, b.*)

Zoarium branching, branches about 1 mm. wide, or slightly less. Cells arranged in diagonal intersecting and in longitudinal series. Longitudinally, 6 cells occupy a length of 2 mm; about 13 longitudinal series surround the stem. Vestibule elongated, smooth, sharply distinguished from the intermediate granule-bearing ridges. Granules strong, readily seen even under a low magnifying power, arranged in one, two, or even three rows along the ridges. At one end of the vestibule a low node is frequently seen. The thin, immature portion of the cells curves gradually outward into the mature portion, where the curvature is increased and the walls become decidedly thickened. The stems branch at intervals varying from 15 to 25 mm.

From the western forms of this species which we have seen, the Ohio specimens show several variations. The branches are much narrower, and instead of 4 cells, 5 cells may be counted in a distance of .05 inch. The vestibules also appear more elongated. However the fact that the branches are narrower would perhaps be sufficient to account for the other variations. Its wide geographical distribution is also of interest in this connection. Meek mentions the species from Nebraska, Kansas, Iowa, Missouri, and Illinois. In species of wide distribution we are accustomed to look for variations, and our specimens are probably the smaller sized form of the same.

Flint Ridge and Bald Hill. Rather common.

III. RHOMBOPORA ————.

(*Plate* VII, *Fig.* 5, *a*, *b*, *c*.)

A fragment showing the same internal features as the last probably belongs to the same species. About 6 cells are found in a distance of 2 mm. in the longitudinal series, and about 8 cells in the same distance in the diagonal series. The apertures are decidedly rhomboid, the ridges bear rounded nodes at their intersections and show faint traces of low granules between the cells. They recall strongly Meek's figures of the type specimens. They seem to us to owe their more decidedly rhomboid character partly to the effects of exfoliation of the outer crust.

CYSTODICTYONIDÆ, Ulrich.

Frond composed of two or more layers of cells, united along their epithecal membranes. Tubular cells with vertical folds or indentations, the remains of the crescent shaped lip. Interstitial spaces occupied by vesicular tissue, not visible at the surface.

GENUS CYSTODICTYA, Ulrich.

Frond composed of two cell layers, branches compressed, dividing dichotomously, with sharp, nonporiferous margins. Cells arranged in diagonal intersecting series, with more or less marked longitudinal series. Interstitial cells arranged in longitudinal series, angular; arrangement more or less disturbed about the cells.

IV. CYSTODICTYA CARBONARIA, *Meek*.

(*Plate* VII, *Fig.* 2; *a*, *b*, *c*.)

Ptilodictya (Stictopora) carbonaria, Meek; Proc. Acad. Nat. Sci. Phil. XXIII, p. 16); Ohio Pal. Vol. II, p. 328.

Fronds dividing dichotomously at intervals from 5 to 15 mm, branches very thin, non-poriferous margin narrow, smooth, or rarely with faint striations. Branches 4 to 4.7 mm. wide, with 9 to 11 longitudinal rows of cells. Cells arranged in diagonal intersecting rows, more or less curved laterally and sometimes separated there by faint grooves. Single undulating striations more less irregular extend longitudinally between the cell rows. Cells, five in a length of 2 mm, seven to eight rows in the same distance in width.

Meek especially mentions the absence of striations, but the species is very common at the locality he mentions, "Newark, Ohio, Coal-measures," namely, Bald Hill, and well preserved specimens, especially clear impressions, readily show the faint undulating striæ otherwise overlooked.

C. lineata, *Ulrich*, has a marked longitudinal arrangement of cells, with marked longitudinal ridges extending between the cell rows. The cells are also fewer in number.

C. occellata, *Ulrich*, has the diagonal series of cells more curved laterally and the separating furrows more marked, forming a distinct feature of specific value. The branches are also wider.

Common at Bald Hill.

GENUS, PRISMOPORA, Hall.

Fronds composed of three cell layers, hence triangular, dividing ("dichotomously," Ulrich, and) trichotomously; sides frequently unequal, concave, margin often serrated. Cells in oblique intersecting rows, approaching the margins in the serrations, distant from the same along the indented area. Interstitial cells in the form of vesicular tissue, not visible at the surface.

V. PRISMOPORA SEREATA, *Meek*.

(*Plate* VII, *Fig.* 6, *a*, *b*, *c*.)

Ptilodictya (Stictopora) sereata, Meek, 1875, Ohio, Pal. Vol. II, p. 327.
Cf. Ptilodictya triangulata, 1878, White, Proc. Acad. Nat. Sci. Phil. p. 35.
  Ptilodictya triangulata, 1879, White, Pal. Papers, No. XI, p. 214.
  Ptilodictya triangulata, 1881, White, Appendix, Rep. of 100th Meridian, p. XXIV.
  Ptilodictya triangulata, 1883, White, Contrib. to Invert. Pal. p. 131.
  Prismopora serrulata, 1884, Ulrich, Am. Pal. Bryozoa, p. 41.

Zoarium dividing; dichotomous branching alone observed, but since the specimens are mostly in casts and never free, it can not be determined with certainty that there was not a third branch. Specimens from Danville, Illinois, found free, are all trichotomously divided as far as we have observed. Branches triangular; the sides sometimes very irregular. The sides are concave, concavity variable, although always distinct. The three edges are all sharp and serrated with wavy margins. The size of the serrations extremely variable; some of the most prominent seen being 1.4 mm. wide, 4 serrations taking up a length of 9 mm. Cell apertures distinctly lipped on one side, the lips not directed in definite related directions as far as known; the apertures are not arranged in well defined lines, however, some arrangement can always be discovered. Usually this consists in a disposition of the cell apertures in oblique intersecting lines across the sides of the branches; one of these oblique series can usually be readily seen, the other set are sometimes imperfectly developed; when these oblique series are both well developed, longitudinal series are necessarily present, although even in that case these longitudinal lines run somewhat diagonally along the stem. In other words, diagonal rather than longitudinal arrangement prevails. In the serrations the cells are always more compactly arranged. Along the indented portions, however, there is always a crescentic space, variable in size, along which there are no cells, the margin is therefore interruptedly celluliferous. As may be imagined from some of the remarks above, the number of cells is variable. In one specimen 5 cells occurred in a length of 2 mm. Interiorly the cells are surrounded by vesicular tissue, irregularly arranged.

Meek clearly did not understand his own specimens; he did not know that the branches were three-sided, but gave a thickness of [illegible] inch to his branches, supposing them to be flat. He also [illegible] tice the distinctly projecting apertures of the cells with irre[illegible] White described his species from the Coal measures at Dan[illegible] Illinois, and states in a later publication that the type specimens were obtained from Mr. William Gurley. I therefore applied to Mr. G[illegible] for specimens he considered authentic, and received all he had. W[illegible] could not recognize the three-sided branches in Meek's descrip[illegible] so proceeded to describe his specimens as *Pt. triangulata.* [illegible] states that the cells are irregularly disposed at the surface. Spe[illegible] at hand, from the original source, however, show the same arrangement of the cells as noted in the Ohio specimens. Indeed, some [illegible] the specimens from Danville show the oblique intersecting series very beautifully. It must be remembered, however, that although diagonal intersecting series are considered typical, most specimens are to some extent variations from this type, however, even then they rather represent cases of disturbed regularity than typically irregular dispos[illegible] The width is stated as varying from 3 to 5 mm, this is broad[illegible] to include our specimens from Ohio, but the average width of the Illinois is less than that of Ohio forms, and in general the size of specimens seems more variable at the former locality. Later in the Appendix to the Report of Surv. W. of 100th Meridian, Pl. IV, Fig. 2, White figured one of the type specimens. This specimen falls below the minimum width given in the original description, being only 2.5 mm. wide, and is figured with scattered cells, irregularly undulating edges and without crescentic nonporiferous portions regularly occupying the incurved portions of the sides. However, since Fig. 2, e, on the same plate, representing a specimen from Cebolla Creek, likewise omits the crescentic non-poriferous characters of the margin, readily seen in the original specimens, it is to be expected that in a small specimen this feature would be entirely overlooked. At any rate the smallest specimen we have from Danville, which is 3 mm. wide, shows the crescentic non-poriferous characters, the arrangement of cells noted in the Ohio specimens, and a regularly undulating margin, all the characters being readily noted when attention has been once called to the same.

Again, specimens from Chester, Illinois, of larger size, but of the same average width as Ohio specimens, show no variations from the latter in any particular. The same is true of the specimens just referred to from Cebolla Creek, New Mexico, Nos. 4480, 9447, and 9472 of the National Museum collections. In his Pal. Papers, No. XI, White describes specimens from the middle Carboniferous series of Yampa Plateau, N. W. Colorado, which are only 2 to 2.5 mm. wide. We found in them the same crescentic nonporiferous spaces as noted above in specimens from other localities. Finally, Ulrich described a form from Tateville and Grayson Springs, Kentucky. It is in every respect similar to the Ohio forms. He states: "This species is readily distinguished from all other species of the genus known to me by its wavy or serrated margins." The three-sided character of Meek's specimen was unknown; White in his original description failed to mention the indentations of the margin, in his second description they are stated to be merely a little irregular, but in his third description the scalloped character so readily noticed in larger specimens is distinctly stated and in one example figured.

The general features of the species therefore consist in regularly scalloped margins; the serrations are not rounded typically, but are more or less accurately truncated, sometimes even slightly concave, the serrations decrease in prominence with the size of the specimens; the indentations are bordered by crescentic non-poriferous spaces; these spaces are large and conspicuous in the larger forms, decreasing to narrow, but distinct proportions in the smaller specimens. The specimens from New Mexico, Kentucky and Chester, Illinois, are undoubtedly the same as our Ohio forms. Those from Colorado are readily connected, it seems, by the variable forms at Danville, Illinois. In conclusion, I desire to express my gratitude to Prof. C. A. White, of the National Museum at Washington, for the ready access to the specimens described by him from western localities. The above discussion is designed merely to present a better understanding of this species, from the abundant material which it has been my good fortune to see.

Common at Bald Hill; rare at Flint Ridge.

ACANTHOCLADIIDÆ, Zittel.

Ramose bryozoa, dendroid, pinnate, or forming fenestrated expansions, consisting of strong central stems and smaller lateral branches proceeding from the margins; the latter uniting in fenestrated genera with the branches of adjacent stems. Stems and branches both poriferous on one side only, non-poriferous dissepiments therefore absent.

GENUS GLAUCONOME, Goldfuss.

Main stem very slender, branches springing from the stem at large angles, often at almost right angles. Celluliferous face of both main stem and branches with two alternating, longitudinal series of cells. Non-poriferous side longitudinally striated.

VI. GLAUCONOME WHITII, *sp. n.*

(*Plate* VII, *Fig.* 4, *a*, *b*, *c*.)

Largest specimen 18 mm. long and 6 mm. wide, evidently not a complete zoarium. The stem is very slender, rounded, and regular in thickness, having a diameter of about .22 mm. On either side are branches, diverging from the stem at an angle varying from 65 to 82 degrees, usually nearer the angle first given. These branches are of two kinds; the smaller kind are very narrow, about .13 mm. wide, and rather short, a millimetre or less is the length of the largest, so far seen; the larger kind are slightly narrower than the main stems, about 1.9 mm. wide, and are longer than the branches just described, the length of the largest branch so far seen being 4 mm; at a short distance from the main stem these also bear very short minute branches. Along the stem the branches are stationed with some regularity, about 4 branches in a length of 2 mm; three to four small sized branches intervene between those of larger size when the latter occur. At a distance of 1.6 mm. from the stem along one of the branches the minute branches mentioned above begin; these are stationed also at equal distances apart, almost 5 in a length of 2 mm. The cell apertures are distinctly elevated above the surface of the stems and cause irregularity in the surface. There is always a cell at each juncture of a branch with the stem, near the smaller angle; and also one half way between the successive branches along the stem. Since the alternation of the cells is regular, the branches are therefore not strictly opposite, although at first sight they may appear so. The presence and arrangement of cells on stems and branches is similar, excepting that on the smaller branches they are stationed closer together, as might be expected. Five to seven longitudinal wavy striæ mark the poriferous side; two of these, somewhat more prominent and almost continuous, though variable in distinctness, form a sort of median keel between the cell rows. An equal number of striæ mark the non-poriferous side; these are quite straight and are covered with numerous minute granules, scattered, or apparently forming three or four rows along the striæ.

Glauconome trilineata, Meek, is readily distinguished by its larger size, flattened stems and branches, and a median trilineate ridge on the poriferous side which is very characteristic. *Gl. nereidis, White*, differs in its larger size, the comparatively small space between the branches, and in the presence of dimorphous pores upon the poriferous side on the convex area between the regular cells.

Moderately common at Flint Ridge. Named in honor of the U. S. Paleontologist, Dr. A. C. White, through whose courtesy I was permitted free access to the valuable collections in the United States National Museum at Washington.

GENUS SEPTOPORA, Prout.

Zoaria fenestrated by the union of the short lateral branches of adjacent stems; cell rows, two; dimorphic pores present. *Synocladia*, *King*, is distinguished by the absence of dimorphic pores, and the presence of more than two rows of cells.

VII. SEPTOPORA BISERIALIS, *var.* GRACILIS, *Meek.*

(*Plate* VII, *Fig.* 7, *a*, *b*, *c.*)

Synocladia biserialis (gracilis, suggested), Meek, Ohio Pal. Vol II, p. 326.

Zoarium flabellate, composed of three or four strong radiating stems, forming a net-work by pinnate division, and the union of opposite, short, lateral branches. Intercalated stems, arising from the coalescing of lateral branches, are not unfrequent. All stems increase in size above. Lateral branches short, inclining at angles of 60 degrees or more to the stems, those of adjacent stems uniting, the union rounded, angular, nodose, or slightly produced. Poriferous face with two rows of cells; alternating with these, usually nearer the margin, although sometimes between the cells, are pores of about one-third the size of the cells. The median ridge is narrow, distinctly nodose, nodes not quite as numerous as the cells on either side. Non-celluliferous face, with the sides sloping from a convex median ridge, which sometimes is indistinct, longitudinally striated, striations strongest along the median area. Dimorphic pores very small, situated singly or in pairs at the junction of the branches with the stems, occasionally a few others scattered about in various positions, but not with the frequency or irregularity indicated by Meek in his figures of *S. biserialis* from the Coal Measures of the West.

From *Septopora biserialis*, *Swallow*, this form may be distinguished by the tendency towards the formation of a median ridge on the non-poriferous side, by the regularity of arrangement of most of the dimorphic pores, both on the celluliferous and non-celluliferous sides, and by the more distant stems and branches, forming larger fenestrules. *S. Cestriensis*, *Prout*, referred by E. O. Ulrich to *S. biserialis* as a variety, differs from our form in wanting the dimorphic pores on the celluliferous side, or at any rate in having them much less numerous. Ulrich's studies indicate great variability in this species, and our form would give it also wide geographical distribution.

The measurements in this case are variable and scarcely specific, but a few may here be given of a specimen considered typical. About 8 stems occur in a width of 10 mm; 9 branches occur in the same length. From the *Fenestellidæ* this species will of course be at once distinguished by the celluliferous character of what might be taken for dissepiments, even if these should unite neatly.

Common at Flint Ridge. (*Gracilis*, slender branches.)

FENESTELLIDAE, King.

Zoaria usually reticulate, poriferous on one side only, branches united by non-poriferous dissepiments or anastomosing; in the latter case there is never a division possible into stems and branches, so that no confusion with the *Acanthocladiidæ* need arise.

GENUS CHAINODICTYON, gen. nov.

Zoaria flabellate or perhaps infundibuliform, branches inosculating, forming a loose net-work, the meshes of which are elongated, elliptical, or oval, somewhat variable (as the openings in the fronds of some *Clathroporæ*). Branches flattened, sometimes even concave on the non-poriferous side. Without longitudinal striæ, as far as known, but with very marked lunate striations or rather folds extending across the non-poriferous sides of the branches, similar to the lines of growth seen on the epithecal membranes of *Stictoporidæ*. Cells in oblique intersecting rows which give rise to three less evident, rather irregular, longitudinal series. (*Chaino*, gaping; *dictyon*, net; alluding to the elongated large meshes of the zoarium.)

Phyllopora, the nearest related genus, has rounded meshes; the branches are far less flattened on the non-poriferous side, and are finely striated longitudinally; on the poriferous side the cells have a more regular arrangement into longitudinal rows; it occurs in older paleozoic formations; *Chainopora* may be considered its later representative.

VIII. CHAINODICTYON LAXUM, *sp. n.*

(*Plate* VII, *Fig.* 8, *a*, *b*, *c*.)

Meshes elongated, rhomboid, elliptical, oval, ovate, and obovate in the same zoarium, typically elliptical, about 2.5 mm. long and 1.3 mm. wide. Branches narrow, about .3 to .38 mm. wide; the cells are arranged in diagonal rows; longitudinally about 5 cells may be measured along the sides of the branches in a length of 2 mm. The cells arise near the nonporiferous side, are quite elongated, and reach the surface at a very oblique angle. Longitudinal arrangement of cells is incidental rather than typical and often obscured, whereas the oblique series remain distinct.

Flint Ridge, rare. (*Laxum*, loose meshes.)

GENUS POLYPORA, McCoy.

Zoarium flabellate or infundibuliform, poriferous on the inside; branches nearly straight, connected at regular intervals by non-poriferous dissepiments. No median keel on the poriferous side of the branches; from two to six rows of cells.

IX. POLYPORA FASTUOSA, *De Koninck.*

(*Plate* VII, *Fig.* 9, *a*, *b*, *c*, *d*.)

Zoarium infundibuliform. Branches dividing dichotomously, rapidly near the centre, then less frequently, becoming straight above. Non-poriferous face with sloping sides, thus leaving a sort of carina along the middle, varying from this to ordinary convexity; the edges of branches acute, frequently more horizontal than the sides of the branches, thus forming a narrow margin along the fenestrules. The dissepiments very prominent, as high as the branches or even exceeding the same, less than a third the width of the branches, narrowly compressed, and consequently carinated. These dissepiments are very characteristic, giving the oval inclosed fenestrules an oblong outline. Branches finely and closely striated longitudinally; dissepiments also striated. Poriferous face convex. Cells arranged in four to six rows, usually four or five rows; the diagonal series however are usually first noticed. Cell apertures small, separated by twice their length longitudinally. The spaces between the cells are longitudinally striated by wavy lines. In another specimen, with the same characteristics on the non-poriferous side, the poriferous face presents larger cells arranged closely together without the intervening striations. The dissepiments longitudinally striated.

The main characters in the identification of this species have been drawn from Dr. Franz Toula, in his descriptions of *Permo-carboniferous fossils from the west coast of Spitzbergen*, 1875, and of the *Carboniferous Limestone Fauna from the Barents Islands, N. W. of Nowaja-Semlja*,

1875. In the latter publication he states of the diagonal arrangement of the cells; "This arrangement is first seen on the branches, when the exterior layer has been removed. This layer, when best preserved, shows distinct longitudinal striations; by abrasion or splitting off, the inner portions of the cells appear arranged as stated above so close to one another that hexagonal outlines arise." And later: "The dimensions of our specimens are very variable; the fenestrated branches named are sometimes broader, sometimes narrower, and in a piece narrower than usual, even 7 fenestrules are found in a length of 10 mm." Apparently the same variations are found in our specimens. The largest has 5 fenestrules and 6 dissepiments in a length of 10 mm., 7 to 9 branches occur in the same distance in breadth. In one of the smaller specimens, 7.3 fenestrules occur in a length of 10 mm. and 10.5 branches in the same breadth. From 7 to 9 cells occupy a length of 2 mm. The fine longitudinal striæ of the poriferous face of the dissepiments are mentioned by Toula in his descriptions.

Common at Flint Ridge and Bald Hill.

Perhaps we have confounded two species in the above description, one smaller than the other, or with smaller and more distant cells, but we fail to find definite specific characters.

GENUS FENESTELLA, Lonsdale.

Differing from *Polypora* in the presence of a median keel, the cells being arranged in two rows, one on either side of the keel.

X. FENESTELLA LIMBATUS, *sp. n.*

(*Plate* VII, *Fig.* 10, *a*, *b*, *c*, *d*.)

In the limestones at Flint Ridge and Bald Hill are found numerous specimens belonging to the genus *Fenestella*, all of which have the following features in common. The zoaria are infundibuliform; the inner side is poriferous; the median keel is well developed and distinct, along the summit it is occupied by a single row of rounded nodes stationed at regular distances apart, and calling to mind such *Polyporæ* as may be typified by *Polypora submarginata*, *Meek*, for instance, (Pal. East. Nebr. Meek, 1872); the nodes often appear hollow, where abraded, but never alternate with small pores as in the species just cited. The nodes are somewhat more numerous than the cells. Another equally characteristic feature is the form and arrangement of the cells. Typically one cell is placed at each corner of the fenestrule at the junction of the dissepiments with the branches, another cell is situated on each side of the fenestrule half way between the two cells already located; the number of cells is therefore typically twice that of the dissepiments; but occasionally two cells may fall in this intermediate region and the next cell is thrust to a position just above the next dissepiment, but the typical distribution is easily recognized in the complete individual. The cell mouths are very large, so that the corners of the fenestrules are rounded and near the middle they are constricted, giving a very peculiar appearance to the fenestrules. The broad cells thus give the branches a ve aracteristic appearance which is suggested in the specific name *lim* , bordered.

Here all similarity ceases. The specin s vary from small, fine, delicate forms, to those which are quite coars It seems bold almost to associate such forms under one specific me, but we fail to find specific characteristics, although we have lant material and prefer to designate one well-defined species, to ng several which intermediate forms refuse to admit. Conside them as one species we have the following description of the non ferous side. Dissepiments from one-fourth to almost one-half size of the branches. Fenestrules oblong, the corners angular, vary g to coarsely granular, then often with quite large granules in dis ongitudinal rows, often longitudinally striated, especially in worn mens. Branches from 10 to 13 in a width of 5 mm., dissepiments 13 in the same length.

As types of this species we take the s st specimens.

XI. FENESTELLA LIMBATUS, *var.* REMOTUS.

(*Plate* VII, *Fig.* 11.)

A variety having all the other features of this species differs only in having the dissepiments relatively farther removed from each other as shown by the following measurements: 10.5 branches occupy a width of 5 mm, 6.5 dissepiments occupy the same distance in length.

Found with the above.

MONTICULIPORIDÆ, Nicholson.

Zoarium with tubular cells, which are thin walled and polygonal below, above they are bent more decidedly towards the surface, are of nearly equal size throughout, more or less thickened and rounded, but never lipped nor separated by vesicular tissue. Zoarium occasionally frondose, but never composed of two distinct layers of cells entirely separated by the epithecal membranes. A distinct section of this family typified by the following genus will no doubt soon be separated from the same and made an independent family.

GENUS STENOPORA, Lonsdale.

Zoarium ramose. Cells of the mature region more or less annulated periodically, with large spiniform tubuli at the angles and straight diaphragms, frequently operculate. Species often erroneously referred to *Chætetes*.

XII. STENOPORA OHIOENSIS, *sp. n.*

(*Plate* VIII, *Fig.* 12, *a*, *b*, *c*, *d*, *e*.)

Branches sub-circular dividing at intervals of about 30 mm. showing faint traces of bilateral arrangement in the immature region. In the immature region the cell walls are thin and polygonal. In the mature region the cell walls become strongly and closely annulated by periodical thickenings, crossed by thin diaphragms at the annulæ. Spiniform tubuli of large size occupy the cell angles, others of smaller size are found on the intermediate cell walls, encroaching below upon the cell cavities as vertical ridges. Well preserved specimens show operculate mouths. Cells irregular in size, the smaller more angular, but not distinguishable in vertical section. About 10 cells occupy a length of 2 mm; branches 5.6 mm. thick.

Locality and position. Flint Ridge.

XIII. STENOPORA CARBONARIA, *Worthen.*

(*Plate* VIII, *Fig.* 13, *a*, *b*, *c*.)

Branches of larger size than the last, 8.9 mm. thick. Cell walls not distinctly annulated; cells larger, crossed by more distant diaphragms, operculate, operculæ visible both in cross and vertical sections, also in hand samples. Large spiniform tubuli at most of the angles of the cells, intermediate spiniform tubulæ wanting. Some specimens indicate interrupted growth in the zoarium. About 7 ce occupy a length of 2 mm.

Locality and position. Bald Hill and Flint Ridge.

Among the Flint Ridge collections corals are exceedingly ra and only one species has so far been recognized, belonging to the following genus.

GENUS CYATHAXONIA, Michelin.

Single polyp cells, with diaphragms, the invaginated centres which form a solid central axis, the cristiform columella. Radial lamellæ well developed, terminating as superficial carinations on the conical centre of the diaphragms. (Rominger, Fossil Corals, Geo Surv. Mich. Vol. III, p. 96).

CYATHAXONIA PROLIFERA, *McChesney*.

(*Plate* VIII, *Fig.* 15, *a*, *b*, *c*.)

Coral conical, nearly straight, or curved below; epitheca thin, marked by distinct vertical ridges locating the apertural and lateral gaps distinctly; calyx nearly circular, deep; radial lamellæ 20–28, beginning as carinations at the mouth of the calyx, slowly enlarging below and ending as ridges on the invaginated diaphragms; alternating with these lamellæ are carinations or secondary lamellæ, which reach scarcely more than half the distance down the calyx, and therefore are seen only in well preserved specimens; the columella compressed laterally, the larger axis in line with the apertural and central gaps, very prominent.

Largest specimen so far found 22 mm. long, and 17 mm. wide at the mouth of the calyx, the calyx is 13 mm. deep, the columella protruding into the same for a distance of 7 mm; the columella is 2.7 mm. wide below, and about 1 mm. thick. The columella is not always so well preserved.

Locality and position. Flint Ridge and Bald Hill.

During the publication of these pages I learned that Mr. E. O. Ulrich was engaged on a similar list of bryozoa from the base of the Coal Measures at Seville, Illinois, for the Illinois Geol. Surv. Vol.

VIII. From his copious notes on the specimens submitted to him for examination, most of the following are extracted.

Rhombopora multipora, n. sp, is found at Seville, Ill.

Glauconome, Goldfuss, is a synonym for *Vincularia, DeFrance,* having been originally used to designate Mesozoic species of the latter genus; our species must therefore be referred to *Pinnatapora, Vine.*

Pinnatopora Whitii, n. sp, is closely related to *P. bellula, Ulrich,* from Seville, differing in the possession of a double ridged median keel on the celluliferous side, and in the absence of distinct granules forming single rows on the striæ of the reverse, 4.3 cells occur in the same distance as 3 cells in *P. bellula, Ulrich.*

Septopora biserialis, Swallow; a form resembling the western types of this species as figured by Meek, is found at a horizon about 100 feet above the Flint Ridge layer, near Brownsville. The branches are more or less wavy, rounded on the non-poriferous side, the dimorphic pores quite numerous, one or two stationed at the junction of the stems with the branches, the rest scattered. The dimorphic pores of the celluliferous side appear usually between the cells, rather than just without the line formed by them, as is more commonly the case in *S. biserialis, var. gracilis.*

Chainodictyon laxum, n. sp, is also found at Seville, Illinois. Generically, the following cell structure is of importance. Arising near the reverse side of the bryozoum the cells are at first somewhat decumbent, then they enlarge, become compressed laterally, and bend towards the celluliferous surface, opening upon the same as elongated oval or elliptical cells more or less bounded on each side by single longitudinal wavy striæ.

Fenestella limbata, n. sp, is very closely allied to *F. mimica, Ulrich,* as figured in the forthcoming Illinois report, pl. LII, fig. 7. The median keel of the Ohio specimens, however, is more prominent and distinct than in that species, but not at all as large as the median keel of *F. Wortheni, Ulrich,* fig. 5, of the same plate.

Fenestella remota, n. sp. (*F. limbata, var. remota, ante*), proves on further examination to be a well marked species, with four cells to each fenestrule, a comparatively broad median keel occupied by a closely arranged series of nodes. The reverse is occupied by distinct longitudinal striæ.

Plate VII.

Fig. 1. *Rhombopora multipora, n. sp;* a, type; b, part of the surface, X 14; vertical section, X 4.5.

Fig. 2. *Cystodictya carbonaria, Meek;* a, frond; b, part of the surface, X 6. 5; c, cross-sections showing indented cells and angular interstitial cells, X 6.5.

Fig. 3. *Rhombopora lepidodendroidea, Meek;* a, fragments; b, part of the surface, X18.

Fig. 4. *Pinnatopora* (*Glauconome, ante*), *Whitii, n. sp;* a, type; b, celluliferous side, X 10; c, non-celluliferous side, X 11; d, section showing internal arrangement of cells, X 11.

Fig. 5. *Rhombopora ? lepidodendroidea, Meek;* a, part of the surface, X 8; b, section; c, the same, X 3.5.

Fig. 6. *Prismopora sereata, Meek;* a. cast, trichotomously dividing at one corner; b, surface; c, cross-sections; d, specimen from Danville, Illinois, dividing trichotomously, with cross-section; e, a side of another specimen.

Fig. 7. *Septopora biserialis, var. gracilis, Meek;* a, non-celluliferous side; b, the same, X 4.2; c, section showing position of cells and dimorphic pores of the celluliferous side, X 8.

Fig. 8. *Chainodictyon laxum, n. sp;* a, zoarium; b, non-celluliferous side, X 3; c, cells, surface view, X 15, and lateral views, X 5.

Fig. 9. *Polypora fastuosa, De Koninck;* a, non-celluliferous side; b, the same, X4; c, celluliferous side, X3, a part, X8; d, another species, a part, X4.

Fig. 10. *Fenestella limbata, n. sp;* a, type; b, celluliferous side, X 11.4; c, non-celluliferous side, X 12 3; d, larger form; e, view of a branch, X 13.

Fig. 11. *Fenestella remota, n. sp.* (*n. var. ante*); a type; b, cast, X 13.

Fig. 12. *Stenopora Ohioensis, n. sp;* a, part of the surface, X 16; tangential section, X 9.5; the same, X 20; d, vertical section of mature portion showing cross-section of annulæ with their connecting cell-wall and diaphragms, also a lateral view of the annulations and three of the vertical thickenings of the cell-wall, which in tangential sections appear as darkened spots in the cell walls, X 12, also a part enlarged, showing that the walls of contiguous cells are not divided from each other, X 18; e, piece of a branch with cross-section showing tendency towards bilateral structure.

Fig. 13. *Stenopora carbonaria, Worthen,* a, part of the surface, X 12; b, tangential section with traces of operculate diaphragms, X 12; c, vertical section indicating periodical growth, with diaphragms interrupted by operculæ, X 12.

Fig. 14. *Phillipsia Shumardi, Herrick;* a, entire specimen; b, detached movable cheek.

Fig. 15. *Cyathaxonia prolifera, McChesney;* a, lateral view; b, section passing through longer axis of columella; c, view of calyx showing columella. (Plate II, Fig. 21, internal cast of calyx.)

Fig. 16. *Septopora biserialis, Swallow;* a, part of a zoarium; b, non-celluliferous side, X 6; celluliferous side, X 7. Specimen found half a mile west of Brownsville, 100 feet above the horizon of Flint Ridge specimens.

II.

THE CLINTON GROUP OF OHIO. PART II.

BY A. F. FOERSTE.

CRUSTACEA.

I.	Acidaspis Ortoni,	n. sp.
II.	Proetus determinatus,	n. sp.
III.	Proetus ———,	
IV.	Illænus Daytonensis,	Hall and Whitfield.
V.	Illænus Madisonianus,	Whitfield.
VI.	Illænus ambiguus,	Foerste.
VII.	Calymene Vogdesi,	n. sp.
VIII.	Ceraurus ———,	
IX.	Lichas breviceps,	Hall.
X.	Phacops pulchellus,	n. sp.
XI.	Dalmanites Werthneri,	Foerste.
XII.	Encrinurus Thresheri,	n. sp.

In the first paper of this series two new species of trilobites were published and a provisional arrangement of the others was made. Since its publication fresh material has been accumulating and a wider literature has been examined, so that many things then left undecided can now be definitely determined. The following pages may therefore be considered a revision.

GENUS ACIDASPIS, Murchison.

I. ACIDASPIS ORTONI, *n. sp.*

(*Plate* VIII, *Fig.* 1.)

Acidaspis ———, D. U. Bull., Vol. I, p. 101, pl. XIII, fig. 23.

Head semi-circular in outline, moderately convex in the
of the glabella, suddenly depressed along the movable cheeks, t
eral effect being to give the head a very convex appearance.

Glabella complex in structure, three-fourths as long as
mesial lobe oblong, its length equal to twice the breadth, with
lateral pairs of lobes; the first pair very small, and near the
anterior border; the second pair of moderate size; the last pair
oblong, occupying almost half the length of the mesial lobe; t
posterior pairs of lobes distinctly separated from themselves a
fixed cheeks by furrows, from the mesial lobe by deep grooves.
cheeks provided with a furrow extending from the posterior part
eyes to the anterior part of the glabella, cutting from the fixed
a lanceolate strip, the pointed end of which lies against the a
border of the middle pair of lobes; along this furrow, beginn
the eye, extends a narrow ridge almost to the anterior pair of
The facial sutures anterior to the eyes begin the ridges just des
and then gradually separate from the same, cutting the anterior
of the head with about the same curvature that the correspondin
of the ridge possesses; posterior to the eyes they extend in a curv
ally, then posteriorly to the posterior border of the head at a
slightly removed from the postero-lateral spine. Occipital ring
rated from the glabella by a groove, of large size, laterally bec
depressed and attenuated, terminating at the groove which se
the posterior pair of lobes from the fixed cheeks.

Movable cheeks with a raised border along the lateral edge
which a number of spines (about ten) extend; at the postero-
edge is quite a long spine; from this spine a border extends
the posterior margin of the head, gradually becoming attenuate
it almost reaches the end of the occipital ring. Owing to the s
and very great depression of the posterior lobes and fixed cheeks
the posterior border of the head, and the position of the oc

groove, the occipital ring seems to extend quite a little distance beyond the posterior border.

A glabella figured by F. B. Meek, in Shumard's Reports for the Geological, Survey of Missouri, for 1855, from the Cape Girardeau Limestone, *Acidaspis Halli*, is a similar species, although much smaller.

Length of glabella in one specimen of moderate size, 8 mm; including the occipital ring, 11 mm; breadth of the mesial lobe, 4.6 mm; including the posterior lobes, 11 mm, between the inner margin of the eyes, 15.3 mm, between the postero-lateral margins, 21 mm; convexity of the head, 5 mm.

Named after Prof. Edward Orton, the distinguished State Geologist of Ohio.

Locality and position. Brown's Quarry, two miles west of New Carlisle, Ohio, Clinton Group.

Genus PROETUS, Steininger.

II. PROETUS DETERMINATUS. *sp. n.*

(*Plate* VIII, *Figs.* 2, 3, 3*a*.)

Bathyurus ———, D. U. Bull., Vol I, p. 103, pl. XIV, fig. 5.

Glabella conical, convex, sharply defined from the remaining portions of the head by a distinct furrow: obscurely marked by three pairs of grooves; the posterior pair being inclined at an angle of forty-five degrees to the axis of the glabella, cutting off the postero-lateral corners; the middle pair, although shorter and less inclined, are still fairly distinct; the anterior pair are very indistinct, quite short, and but slightly inclined; in addition three very indistinct pairs of pits may be seen, the two anterior pairs are at the ends of the two anterior pairs of grooves, the posterior pair are opposite the middle of the posterior grooves. In the very distinct occipital furrow beneath the postero-lateral corners of the glabella are two almost triangular tubercles which add to the conical appearance of the glabella. The occipital ring, broad at the middle, narrow at the ends, is supplied with a distinct granule near the centre.

The anterior margin of the head is curved downwards, giving this portion of the head a distinctly convex appearance; the edge is narrow, but plainly elevated at an angle of perhaps forty degrees with those parts of the anterior margin immediately adjacent. The palpebral lobes are rounded, and are situated opposite the anterior half of the posterior furrows. The facial sutures anterior to the palpebral lobes curve slowly outward toward the anterior edge, then suddenly inward again cutting the edge beyond a line passing through the lateral edge of the tubercles.

In this genus the facial sutures behind the eyes are parallel for a short distance, then curve outward and reach the posterior border of the head, usually at a point half way between the glabella and the postero-lateral margin of the head. In *Cyphaspis* the posterior furrows become deep grooves, dividing the glabella into three distinct lobes, of which the central lobe is obovate in form. The middle and anterior furrows are usually wanting. The tubercles found in the Ohio species have not this signification, but are caused by the bifurcation of the occipital furrow.

Length of smaller specimen, glabella, 3.5 mm; including anterior margin, 5 mm. Breadth of glabella, 3.1 mm; including palpebral lobes, 4.5 mm; width measured between the antero-lateral margins of the area anterior to the glabella, 4.5 mm. Length of the larger specimen, glabella, 7 mm; including occipital ring, 8.2 mm; including also anterior margin, 10 mm. Width of glabella just above the tubercles, 7 mm.

Name signifies *bounded, outlined, the limits established*, and refers to the distinct outline given to the glabella by the surrounding furrow.

Locality and position. Soldiers Home, near Dayton, Ohio. Clinton Group.

III. PROETUS ———.

(Plate VIII, Fig. 5.)

Fragments of the glabella of a species are found which are readily seen to be distinct from the species just described, but which do not admit of a definite determination. There is no distinct, flat border anterior to the glabella; instead, the broad groove lies close to the glabella anteriorly, separating from the same laterally, and defining the raised rim along the anterior edge of the head. This rim makes an angle of 45° with the adjacent parts of the head. Only one set of grooves is distinctly visible and that is the pair along the postero-lateral margins of the glabella. They begin within the anterior portion of the palpebral lobes and are directed backwards and inwards at the same time. Tubercles and posterior parts of the glabella are unknown.

Length of glabella, 3.5 mm, including the rim, 4.7 mm; distance between edges at junction of facial sutures with the anterior outline of the head, 3.7 mm.

Locality and position. Brown's Quarry. Clinton Group.

GENUS ILLÆNUS, Dalman.

IV. ILLÆNUS DAYTONENSIS, *Hall and Whitfield.*

(*Plate* VIII, *Figs.* 6, 7.)

At Brown's Quarry a head of this species was found by Prof. W. S. Hoskinson, of Wittenberg College, which presents the movable cheeks and the rostrum in position. Unfortunately the postero-lateral regions of the movable cheeks are broken off. The character of the rostrum may be easily seen from the figure. The facial sutures extend along the anterior border of the head, of which the rostrum appears a continuation. The movable cheeks become attenuated anteriorly and take a twist which gives their surface a direction in the same plane with the rostrum, against which their tips are accurately fitted.

Locality and position. Soldier's Home Quarries, Brown's Quarry, Ludlow Falls (movable cheek and part of a glabella), Fair Haven (a pygidium), Fauver's Quarry (a pygidium). Clinton Group.

In Ohio this species is the most widely distributed and most characteristic form of the Clinton Group. It would be interesting to know if this is also the case in Wisconsin and Illinois, where similar specimens are said to occur (Ohio Pal. Vol. II, p. 120).

I have seen this species in the collections of the Central Park Museum, labeled Hamburg, Illinois.

V. ILLÆNUS MADISONIANUS, *Whitfield.*

(*Plate* VIII, *Figs.* 8, 9, 10, 10a.)

Since the publication of the last paper little has been added to the knowledge of this species. In that paper two specimens were described. The first pigidium from Huffman's Quarry was very convex and had the anterior edge arching decidedly forwards. The other specimen from Stolz's Quarry was much flatter, broader and less arching anteriorly. At Brown's Quarry numerous pygidia are found, which approach the latter specimen, although sometimes quite convex and more or less arched anteriorly. Associated with these pygidia are glabellæ, which would be referred to *Illænus ambiguus* without hesitation, if the corresponding pygidia were found. However the following slight distinctions may be discovered. The anterior margin is less curved, the curve of the facial suture anterior to the palpebral lobe is less marked, the glabella is less convex, especially along the median line. All of these characters in themselves would hardly give rise to a new species. Whether there are two species with different pygidia, but very similar glabellæ, is unknown. If not, the glabellæ of Brown's Quarry must be referred to *Illænus ambiguus*. Lieut. A. W. Vogdes writes to me, as Prof. Whitfield's opinion, that the pygidia are related to those of *Illænus insignis, Hall,* as figured in N. Y. Report of State Cab. 20. But these evidently do not belong to the glabella which typifies the species. Hence in either case the affinity of the pygidia of Brown's Quarry remains undecided. More material is perhaps necessary to determine this question definitely.

Locality and position. Huffman's Quarry, Stolz's Quarry, Brown's Quarry, Clinton Group.

VI. ILLÆNUS AMBIGUUS, *Foerste.*

This species was founded upon a number of pygidia and glabellæ which have a wide range and are usually found associated together. In the first paper, figure 10c, of plate XIV, is inaccurate, representing the upper length of the grooves as being very distinct, whereas in reality this part is very faint and the pits at the extremity of the grooves seem to be isolated, if the glabellæ be not carefully examined.

Locality and position. Soldiers' Home Quarries, Fauver's Quarry (pygidium and fragment of glabella), Fair Haven (pygidium). Clinton Group.

A hypostoma, not very unlike that figured by Billings under *Asaphus Pelops*, is found at the Soldiers' Home (Plate VIII, Fig. 11). I am uncertain with what Clinton forms to place it. It is certain at least that the hypostomæ of the genus Illænus figured by Gerhard Holm, in his work on the Swedish species, are very unlike the hypostoma in question.

GENUS CALYMENE, Brongniart.

VII. CALYMENE VOGDESI, *sp. n.*

(*Plate* VIII, *Figs.* 12, 13, 14, 15, 16.)

Calymene Blumenbachii? Brongniart, D. U. Bull., Vol. I, p. 110, pl. XIII, fig. 25.

Calymene ———. D. U. Bull., Vol, I, p. 109, pl. XIII, fig. 24.

Calymene Clintoni, Vogdes, 1882, Acad. Nat. Sc., Phila., Proc., p, 178, fig. 3.

Head semi-circular, moderately convex. Glabella with three lateral pairs of lobes; the posterior pair triangular-oval and well defined; the middle pair half the size of the latter; the anterior pair small. Glabella depressed towards the occipital furrow, defined from the anterior half of the fixed cheeks by very deep furrows which merge into a groove, defining the anterior part of the glabella, and separating it from the anterior border. Palpebral lobes slightly anterior to the middle lobes of the glabella. Fixed cheeks and adjacent parts of the movable cheeks, greatly elevated, curving rapidly downwards towards the sides and furrowed along the border by a deep, broad groove, which, anterior to the fixed cheeks, merges into the grooves defining the glabella. Just in front of their junction a low tubercle is seen on either side of the border.

The anterior border is quite long, about one-third the length of the glabella, depressed posteriorly along the glabella forming a groove, otherwise quite flat, not arched in the middle, and elevated at a slight angle above the plane formed by the base of the head. Facial sutures parallel anterior to the eyes along the fixed cheeks, then curving slightly outward and inward again to the anterior edge of the head.

Thorax trilobate; the mesial lobe convex; lateral lobe broader, at first horizontal, then curved backwards and downwards; pleuræ grooved anteriorly, about one-third of the pleura lying in front of the groove; extremities of the pleuræ unknown.

Pygidium strongly curved, almost semi-circular anteriorly, moderately curved posteriorly, almost straight behind the mesial lobe. Mesial lobe tapering posteriorly; the anterior portions indefinitely known on account of the broken condition of the specimen, but apparently there is a half segment, followed by six segments, terminating in a wedge-shaped piece, rounded behind and equal in length to the last three segments. Lateral lobes with segments strongly curved to conform with the anterior and lateral margins of the pygidium, the last pair bordering upon the grooves which divide the mesial from the lateral lobes. The last pair of lobes, together with the posterior border, give the mesial lobe the peculiar appearance of terminating in a box, or rather an enclosure which is bounded on two sides by raised lines almost parallel, and on the third side by the posterior outline of the pigidium.

The size is readily enough obtained from the figures and from the description of the form formerly described under *C. Blumenbachii.*

Associated with these specimens are others of smaller size, described under a separate heading in the first paper, but now believed to be identical. They vary from the typical forms in possessing a less distinct groove along the anterior edge of the glabella, the groove almost merges into the flattened surface of the anterior border, the tubercles at the junction of the lateral and glabellar furrows are scarcely visible, often obsolete and the border appears raised at a somewhat higher angle. However, it is now believed that the larger specimens present the features of the smaller forms in a very marked degree, magnifying their characteristics so as to seem distinct.

Lieut. A. W. Vogdes finds a form at Catoosa Station, also in the Hematitic bed at Dug Gap, Clinton Group, Georgia. This he identified with *Calymene Clintoni, Vanuxem.* Expressing the belief that the Ohio specimens should be referred to the same species, he requested the loan of my specimens, and sent me his in return. The identity of his specimens with mine is apparent. The anterior border has been flattened down by pressure, the groove anterior to the glabella is thus made indistinct, the irregularities of the border immediately in front of the groove appear as indistinct low tubercles, or rather an uneven raised line is formed defining the groove immediately anterior to the glabella.

Since Lieut. A. W. Vogdes had access to the type specimens of *Calymene Clintoni*, at the Am. Mus. of Nat. Hist., Central Park, N. Y. and I doubted the identity of Ohio forms with these, I requested him to compare the specimens, and give me an expression of his opinion. He did so very kindly and thoroughly. Considering the very great similarity of the species of Calymene, and the synonomy to which this leads, it is considered desirable to distinguish a new species carefully from all others with which it might be associated. The following notes are therefore extracted from the correspondence of Lieut. A. W. Vogdes.

The first is the well known *Calymene Blumenbachii* of the Wenlock Series of England. The forms of this species represented by Salter (Paleont. Soc. Vol. 1863, pl. 8, figs. 7–16; pl. 9, figs. 1–5, var. Auctorum), approach the American species. The head represented on plate 9, fig. 1, from the Lower Wenlock Grits (Niagara Series), shows a wide frontal margin similar to the Ohio and Georgia forms; the head figured on plate 9, fig. 1a, has a straight anterior margin with a narrow limb, whereas the American forms have this part rounded with a comparatively broad limb. The pygidia figured by Salter, plate 8, fig. 8c, and plate 9, fig. 1b, have a general similarity, although the Ohio forms show a tendency to extend their side ribs more to the rear, giving the pygidium a semi-circular outline.

The Bohemian Upper Silurian form described by Barrande (Syst. Sil. Boheme, Vol. I, pl. 19, figs. 1–19, *Calymene diademata*, Etage E) represents a form with a broad frontal margin (pl. 19, fig. 12), thickened and incurved; whereas, the Ohio species has its frontal margin extended, the anterior border of the head forming a broad and even curve about the head, turned slightly upwards and not arched in the middle, the limb being exceedingly broad and separated from the anterior margin of the glabella by a deep groove. Barrande's figure, pl. 19, fig. 18, represents a broadly rounded pygidium, the axis being anteriorly broad, and tapering posteriorly, marked by six axial rings. The sides are marked by five bifid segments. The Ohio species has a semi-circular pygidium, the posterior margin being almost straight. The axis is broad anteriorly and tapers posteriorly to a rounded extremity, marked by nine well defined axial rings. The sides have five bifid segments, and a posterior undivided pair. The anterior segments being extended backwards to such a degree as to form a semicircle.

Angelin's figures of *Calymene spectabilis* (Pal. Scand. pl. 19, fig. 5, Reg. E), which Salter refers to *Calymene Blumenbachii*, lacks the broad frontal margin of the Ohio forms. The pygidium of this species as represented by Angelin's figure shows the common rounded posterior margin of the English species, *Calymene Blumenbachii*.

The American *Calymene Clintoni* is distinguished by the smooth side lobes of the pygidia. It is found in the Niagara Group shales, at Rochester, N. Y., below the falls.

Calymene mammillata, *Hall*, (Geol. Rep. Wis. 1861, p. 50), from the shales above the Trenton Group, has "its anterior border extended in front of the glabella in a broadly rounded, thickened projection which is abruptly recurved at the margin and marked on each side by a mammilliform tubercle." Only the largest Ohio specimen shows signs of the tubercles, and the margin of none of the specimens is recurved. It is hoped that with these comparisons the character and extent of this species may cause no trouble.

Named after Lieutenant A. W. Vogdes, who has aided so much in the elucidation of this species.

Locality and position. Allen's Quarry, Soldiers' Home Quarries, Ohio; Catoosa Station, Hematitic bed at Dug Gap, Georgia; Clinton Group.

GENUS CERAURUS, Green.

VIII. CERAURUS ———.

(*Plate* VIII, *Fig.* 17.)

This species, known only by a single glabella, is distinct from any known to me in the same series of rocks. However, it is not deemed wise to give it a specific name, since that might only lead to unnecessary synonomy.

Glabella oval, convex, the posterior border inclined to be straight, with three pairs of furrows; the posterior pair are situated about a third of the length of the glabella from the posterior margin of the same, they curve gradually inwards and backwards, causing the glabella to appear lobate. A little in front of the middle of the glabella is the second pair of furrows, which are shorter. In front of these are the anterior furrows, not so decidedly curved backwards. All these furrows appear to consist of two narrow furrows running very close together in a narrow groove. The little trace of the occipital groove remaining indicates that the occipital ring was strongly depressed towards either side.

Locality and position. Brown's Quarry, Clinton Group.

GENUS LICHAS, Dalman.

IX. LICHAS BREVICEPS, *Hall.*

(*Plate* VIII, *Fig.* 18, 19.)

Since the publication of the first paper, numerous specimens have been found at John Brown's Quarry. The structure of the head is now better understood, and the following description represents the present knowledge of the same.

Glabella trilobate. The middle lobe broadly rounded anteriorly, laterally deeply incurved and almost parallel, posteriorly produced on either side something like an apothecary's pestle. Lateral lobes long, sub-reniform, lying against the incurved portion of the mesial lobe, bending about the pestle-like base of the latter. Palpebral lobes reniform, the convex side turns outwards, the anterior part attenuated, the inner side depressed and defined from the fixed cheeks by a groove more or less distinct. Fixed cheeks between the eyes and glabella are ovate in form, at the base, however, they extend laterally along the posterior part of the head, the facial sutures cutting the posterior margin of the same. Between the fixed cheeks, the lateral lobes of the glabella, the tips of the mesial lobe, and the occipital ring, lie on either side small laterally extended tubercles, well defined by furrows.

The hypostoma of this species is frequently found. The figure will readily enough distinguish the same.

Locality and position. Brown's Quarry, Soldiers' Home Quarries, Fair Haven (a glabella), Clinton Group.

GENUS PHACOPS, Emmrich.

X. PHACOPS PULCHELLUS, *sp. n.*

(*Plate* VIII, *Fig.* 4, 20, 21.)

Arionellus ———, D. U. Bull., Vol. I, p. 114, pl. XIV, fig. 3,

Head semi-circular, convex. Glabella convex and broadly rounded anteriorly, narrowed posteriorly, marked by three sets of grooves, all of them curved, the convex side being directed upwards or inward. The first set consisting of two pairs of grooves are horizontal, the rest extending from the lateral terminations of the latter upwards and outwards. In *Dalmanites* these pairs become confluent at the adjacent terminations and form the grooves distinguishing the anterior lobe of the glabella, so characteristic of that genus. The second set are also horizontal, the inner ends being directed slightly upwards. The third set separates the anterior portion of the glabella from the remainder, extending across the axis as an indistinct shallow groove. Between the third set and the well defined occipital furrow the glabella becomes suddenly depressed and compressed laterally, forming a sort of pedestal for the anterior portions of the glabella. The eyes are large. The occipital furrow continues as a well defined groove along the posterior margin of the head. The border anterior to the head is narrow. The character of the postero-lateral corner of the same is unknown, but judging from the usual characters of the genus it was probably slightly rounded and destitute of spines. The facial sutures follow closely the anterior outline of the glabella to the palpebral lobes, from the posterior parts of these they proceed laterally, cutting the lateral margins of the head a short distance above the postero-lateral corners. Viewed directly from the front the facial sutures are seen to be slightly depressed along the middle of the anterior edge of the glabella. The same is true of the adjacent rim of the head.

Length of largest specimen found, 6 mm; breadth, about 9.0 mm. Length of glabella to occipital furrow, 5 mm; greatest width, 5.7 mm, width just above the third set of furrows, 3.1 mm. Associated with these forms is a pigidium which is similar to that of *Proetus planimarginatus*, *Meek*, of Ohio Devonian strata, but which is placed here both on account of its relative frequency at the Soldiers' Home and because other species, undoubtedly of this genus, possess similar pygidia.

These pygidia are broad; the curvature of the anterior edge is moderate: the middle lobe is prominent and very convex, ending abruptly posteriorly; segments about nine in a well developed specimen, each segment with a tubercle, these forming a median row. Lateral lobes moderately convex, with seven or eight segments, becoming indistinct posteriorly. Segments all grooved along the middle, that part of the pygidium which lies behind the termination of the middle lobe does not show evident segmentation. Posteriorly the margin is thickened along the edge of the pygidium, so that a groove is formed within the posterior edge leaving a plane margin which vanishes anteriorly.

In *Proetus planimarginatus* the central lobe of the glabella has similar groovings, but the postero-lateral margins are enlarged; there is no flat border between its anterior margin and the groove running along the edge of the head, the tubercles are also smaller and more nearly rounded. The pygidia have the same general form and the same median row of tubercles along the middle lobe, but the groove extends all around the lateral and posterior margin, and leaves a continuous border, from which it derives its name.

Length of pygidium, 7 mm; breadth, 12 mm; width of anterior portion of middle lobe, 4 mm, near the posterior termination, 2 mm; the marginal groove vanishes between the third and fourth segments of the lateral lobes.

Name signifies *small* and *beautiful*.

Locality and position. Soldiers' Home Quarries. Confounded by collectors with small specimens of *Dalmanites Werthneri*. Clinton Group.

GENUS DALMANITES, Emmrich.

XI. DALMANITES WERTHNERI, *Foerste*.

(*Plate* VIII, *Figs*. 22, 22*a*, 23, 24, 25.)

The figures of this species, omitted from the original description, are added here, for readier determination.

Locality and position. Soldier's Home Quarries, Clinton Group.

GENUS ENCRINURUS, Emmrich.

XII. ENCRINURUS THRESHERI, *sp. n*.

(*Plate* VIII, *Fig*. 26.)

Pygidium, on account of the great compression and depression of the lateral lobes, is longer than broad. The general form is triangular, highly arched along the entire length of the mesial lobe. Mesial lobe broad anteriorly, becoming gradually attenuated posteriorly, crossed by segments, about 18 in number, becoming indistinct posteriorly. The segments are all more or less interrupted along the mesial line of the lobe, and beginning with the anterior segment, each third segment is supplied with a tubercle, *i. e*, the segments, 1, 4, 7, 10, 13 and 16. The suppression of the middle part of the anterior three segments is less evident. The lateral lobes are marked by seven segments. The anterior segments are directed laterally for a short distance and then are deflected in a broad curve to the rear. The posterior deflection of the succeeding segments becomes more marked until the seventh pair extends in a parallel direction backwards from the mesial lobe. The inner terminations of the interrupted segments of the mesial lobes form low nodules, often indistinct. A similar set may sometimes be distinguished along the edges of the mesial lobe. The segments of the lateral lobes are narrower than the intervening grooves, and supplied with three or four sets of indistinct nodules.

Encrinurus deltoideus, Shumard, from the Cape Girardeau Limestone, Missouri, may be distinguished by its rounded extremity, its greater number of segments (24) along the mesial lobe, and also along the lateral lobes (8 segments). The segments of the lateral lobes are twice as wide as the furrows between them, and are devoid of nodules.

Encrinurus nereus, Hall, from the Racine beds of Wisconsin, may be distinguished by the greater number of segments (8 or 9) on the lateral lobes, as far as known not tuberculated; judging by the figure of the type specimen a raised narrow, but distinct ridge runs along the lateral borders of the middle lobe.

Encrinurus Americanus, Vogdes, from the Clinton Group of Georgia, may be distinguished by the smaller number of segments (6) along the lateral lobes; the segments are almost twice as broad as the deep intervening grooves, are flat and even slightly grooved along the top, and are destitute of nodules, as far as known.

Encrinurus elegantulus, Billings, from the Anticosti Group of Canada, may be distinguished by the greater number of segments (24) along the middle lobes, the anterior 8 extending entirely across, the rest being interrupted, the free mesial space without tubercles. There are only 5 pairs of segments on the lateral lobes. They agree however in the origin of the segments of the lateral lobes, when compared with the position of the segments on the middle lobe.

Encrinurus ornatus, Hall and Whitfield, from the Guelph limestones of Ohio, may be distinguished (if the figures of the type specimen are correct) by the segments of the lateral lobes having a less abrupt backward direction, and being all situated along the side of the middle lobe (whereas in *E. Thresheri* the seventh pair extend posteriorly from the same). The arrangement of the mesial tubercles along the middle lobe is also different, being situated on the second, fifth, ninth, thirteenth, seventeenth, and perhaps one on a later segment. If now the tubercle on the second segment be omitted the remainder are evidently seen to be separated each time by three segments (instead of by two as in *E. Thresheri*).

Encrinurus punctatus, Wahlenberg, of Sweden and elsewhere in Europe, may be distinguished, it is said, by a single row of nodes along the middle of each lateral lobe (whereas the fourth segment of the lateral lobes in *E. Thresheri*, shows 4 tubercles, and the anterior segments probably presented more.

Encrinurus punctatus, Hall, from the Clinton Group of New York, if it be identical with *Encrinurus ornatus*, will of course be distinguished by the same characters as those mentioned under that species; the number of tubercles or nodes in the New York and Ohio Clinton specimens and the size of the pygidia, however, agree better than when the pygidia of the New York and Ohio Guelph specimens are compared. At any rate, the Clinton forms are distinct from the typical specimens of *E. punctatus* from Europe, and from the species described as *E. ornatus*, from the Guelph strata of Ohio.

Named after Mr. B. B. Thresher, of Dayton, in whose cabinet the type specimen is found.

Locality and position. Clinton Group.

GASTEROPODA.

GENUS BUCANIA, Hall.

BUCANIA TRILOBATA, *Hall.*

(*Plate* VIII, *Fig.* 33, *a*, *b*.)

Shell convolute, volutions in the same plane, contiguous; laterally compressed. Body of the shell strongly lobed, the dorsum being laterally compressed and thus separated by a sort of groove from the lateral portions of the volution, giving rise to one dorsal and two lateral ridges or lobes. The form of the aperture is not seen in our Ohio specimens, but would naturally conform to the trilobate structure of the last volution.

Authors are inclined at present to abandon the genus *Bucania*, and to place the forms referred to it among the *Bellerophons*. We have seen fit to retain this name in this case purely as a matter of convenience. There is already a species called *Bellerophon trilobatus*, described by Sowerby, in his "Silurian System", a European form. From this our form may be readily distinguished by the lateral compression of its last volution. The European form on the other hand has this volution decidedly flattened transversely, being elliptical in section; the middle lobe is comparatively much broader and not so much elevated above the lateral lobes. Our specimen differs from the New York types chiefly in size, being comparatively exceedingly small.

It may be noted, however, in this connection that it is associated with a number of small fossils, which apparently are depauperate forms of other, well-known species.

Locality and position. Beavertown marl, Huffman's Quarry. Clinton Group.

LAMELLIBRANCHIATA.

GENUS PTERINEA, Goldfuss.

PTERINEA BRISA, *Hall.*

(Plate VIII, Fig. 30.)

Since the description of the specimens from the Soldiers' Home Quarries, a large number of quite perfect specimens have been obtained from Brown's Quarry, near New Carlisle. A very fine specimen, belonging to the cabinet of Prof. W. S. Hoskinson, is here figured.

They are all left valves. The body of the shell is obliquely sub-ovate, extremely inequilateral; the anterior wing is rather long, and distinctly sinuate at its junction with the body of the shell; the posterior wing is acute and extends almost if not quite as far as the posterior extremity of the shell. The umbo is prominent, rising above the hinge-line. The anterior wing is depressed antero-laterally along the hinge-line, giving sometimes the deceptive appearance of a hinge-line strongly bent at the beaks (as in figure 9, plate 28, Geol. Surv. Ind., Eleventh Report). The surface is marked by numerous distinct radiating and concentric striæ.

Our specimens compare very well, as near as we can judge, with the type figured from Bridgeport, Illinois. The Indiana specimens referred to this species have a comparatively greater width, measuring vertically from the hinge-line; the concentric striæ are usually in the form of prominent lamellæ, recurving at their edges, often fimbriated, characters which our specimens never present.

Length of one of the largest specimens, measured from the umbo to the posterior extremity of the hinge-line, 18 mm, to the posterior extremity of the body, 21 mm; width measured from the hinge-line vertically, 14.5 mm.

Locality and position. Brown's Quarry, Soldiers' Home Quarries. Clinton Group.

BRACHIOPODA.

I.	Streptorhyncus tenuis, ...	Hall.
II.	Strophomena patenta, ...	Hall.

GENUS STREPTORHYNCUS, King.

I. STREPTORHYNCUS TENUIS, *Hall.*

(*Plate* VIII, *Figs.* 31, 32, 38.)

Shell quite large, semi-circular; cardinal line less than the greatest width of the shell, cardinal extremities rounded. Ventral valve flat, the beak and immediately adjacent portions slightly elevated. In the description of the type specimens this valve is said to be slightly concave. Our valve can not be said to be anything more than flat. Dorsal valve moderately convex, the umbo not prominent; convexity, with the exception of a little compression near the cardinal extremities, regular.

Surface marked by numerous, rounded, radiating striæ, somewhat curved near the cardinal extremities; alternating with these are smaller thread-like striæ. These radiating striæ are crossed by fine concentric striæ, presenting when magnified, a beautiful, rugose appearance. Substance of the shell very thin.

One of the largest ventral valves is 30 mm. long, and 36 mm. wide. Our specimens therefore do not attain the size of the Indiana specimens. A dorsal valve is 22 mm. long, 30 mm. wide, and measures 26 mm. between the cardinal angles; its convexity is about 3.2 mm.

Locality and position. This is quite a common species in one part of the Soldiers' Home Quarry. Clinton Group.

GENUS STROPHOMENA, Rafinesque.

II. STROPHOMENA PATENTA, *Hall.*

(*Plate* VIII, *Fig.* 34, 35, 36, 37.)

Leptæna patenta, Hall, 1852, Pal. New York, Vol. II.

Strophomena patenta, Hall, 1859, 12th Ann. Rep. Cab. Nat. Hist. of New York.

Strophomena euglypha, Roemer, 1860, Sil. Fauna, West. Tennessee.

Strophomena patenta, Hall and Whitfield, 1875, Pal. Ohio, Vol. II.

Shell of moderately large size. At various stages of growth they

present a very different appearance, so as often to suggest distin
cies, as may be noticed by the following descriptions.

Ventral valve, length 6.7 mm, width 8 mm. Valve mod
convex, the cardinal extremities compressed, umbo moderately
nent. The corresponding dorsal valve is moderately concave, g
concavity near the beak.

Ventral valve, length 11 mm, width 14 mm. Valve strong
vex, especially at the umbo which is about one-third the distanc
the beak to the anterior margin; the cardinal extremities comp

Ventral valve, length 15 mm, width 19 mm. Valve con
pecially at the umbo, which is one-fourth the distance from the
the anterior, lateral, and postero-lateral extremities flattened o
pressed. The corresponding dorsal valve is slightly concave, its
est concavity being about one-fourth the distance from the beak.
cardinal extremities are quite flat.

Ventral valve, length 18 mm, width 24 mm. Valve with c
extremities quite flat; the regions about the umbo, which is o
the distance from the beak, convex; moderately concave beyo
centre, towards the anterior and lateral margins. These marg
the dorsal valve are slightly convex.

Ventral valve, length 25 mm, width 33 mm. Concave in g
with a convex umbo, whose greatest convexity lies at about one
the distance from the beak. The dorsal valve concave with th
rior and lateral regions moderately convex. This is of the form
New York specimens which formed the type of this species.
never seem to arrive at the stage presently to be described; th
tions are also coarser than those of the Ohio forms.

Ventral valves, length 28, width 35. Valves convex for
half their length, the umbo being very close to the beak, beyor
middle anteriorly and laterally they become strongly recurv
geniculate in some individuals. The corresponding dorsal va
moderately concave for half its distance, then strongly bent or g
late for the remainder of the distance towards the anterior and
margins.

Shell marked by numerous, fine, radiating striæ; in young
mens certain of the striæ at more or less regular intervals b
more prominent, in the typically strophomenoid manner. In
specimens, the prominence of these striæ no longer is sufficient
tract attention, or is even entirely lost. After the removal of th

exterior crust, these striæ often appear as radiating series of papillæ, especially prominent and distinct near the anterior and lateral margins.

Locality and position. Soldiers' Home Quarries, Fauver's Quarry, Centreville. Clinton Group. Also in New York and Tennessee.

GRAPTOLITIDÆ.

I.	Dictyonema pertenue, ...	n. sp.
II.	Dictyonema scalariforme, ...	n. sp.

GENUS DICTYONEMA, Hall.

I. DICTYONEMA PERTENUE, *sp. n.*

(*Plate* VIII, *Figs.* 27, *a*, *b.*)

Frond infundibuliform, composed of numerous slender branches connected at intervals by fine transverse dissepiments, thus forming a fenestrated expansion. The branches are more or less cylindrical in form, about .23 mm. broad, and from 1.3 to 2 times their own width distant from another; they increase by dichotomous division, adjacent branches are parallel, about 9 branches occupying a width of 5 mm. The dissepiments are very fine, about .025 mm. thick; owing to their fineness they can not be readily discovered in all parts of the fronds, nor can their arrangement be accurately determined, but on an average they seem to be about 1 mm. or slightly less apart. Non-celluliferous face marked by strong, short, curved striæ, suggestion the appearance of twisted strands. The celluliferous face has not been seen, however abraded specimens frequently leave impressions of the cells in the rock from which the following characters are drawn up. Cells, circular at their apertures and protruded from the surface of the frond, arranged in a single, straight series along the middle of the branches. The cells are about .18 mm. in diameter, and a little more than their own width apart, about 12 cells occupying a length of 5 mm. The frond from which this description was prepared is a flabellate fragment 23 mm. in length.

The name signifies *very slender*.

Dictyonema pergracile, Hall and Whitfield, is described as a species in which the branches do not exceed .5 mm. Our specimens are only half that size, but since the minimum width in the Kentucky specimens is not mentioned, this can not assist in the identification of our specimens. However the branches of our specimens are not evidently tortuous, nor are the fenestrules elongate hexagonal in form.

Dictyonema splendens, Billings, is said to have "longitudinal stems about one-third of a line wide, and about their own width distant from each other. There are five or six longitudinal stipes in the width of two lines," a very suggestive mathematical problem. Giving it a fair interpretation, there are 5 or 6 branches instead of 8 in a width of 2 lines, and the branches are probably somewhat broader than in our own specimens.

In neither case is any mention of the cells made. All three forms may eventually prove to belong to the same species. At present, however, our form appears a well defined species with close and narrower branches than any hitherto described.

Locality and position. Soldiers Home, near Dayton, Ohio. Clinton Group.

II. DICTYONEMA SCALARIFORME, *sp. n.*

(*Plate* VIII, *Figs.* 28, 29.)

Frond infundibuliform. Branches of medium size, from once to twice their own width distant from each other, dividing dichotomously and connected by transverse bars or dissipiments one-fourth or one-third their width. The dissepiments are stationed at unequal distances from each other, varying from once to twice the distance between the branches, and leaving quadrangular or oblong fenestrules between the same. The celluliferous side of the frond has not been seen; in places however where the frond has been abraded the position and the frequency of the cells is distinctly shown. Judging from this, they are placed in a single row along the middle of each branch; there are about 13 cells in a length of 5 mm; these cells seem to have an oblique upward direction, consecutive cells leaning upon those in front of thêm, thus forming a narrow ridge or keel; at their tips the cells seem to have become more or less free, and to have developed circular apertures. Non-celluliferous face striated obliquely by short, curved striæ suggesting twisted strands.

Frond here described, a flabellate fragment, 40 mm. long and 35 mm. broad. From 10 to 12 branches occupy a width of 10 mm, and from 10 to 13 dissepiments occupy the same distance in length. The branches where they are well preserved, are from .5 mm. to .65 mm. wide. The dissepiments vary from .1 mm. to .22 mm. in thickness.

The name signifies *ladder shaped.*

This species is evidently related to *Dictyonema retiforme*, *Hall*, differing from the same in the narrower branches being more compactly arranged, the dissepiments likewise occurring at shorter intervals. According to Prof. J. W. Spencer the branches of *D. retiforme* are on an average about one millimetre in width. The largest branches of our specimens do not attain this width.

Locality and position. Soldiers' Home, Clinton Group.

Graptolites of this genus usually appear as black strands on the surface of the rock. In this connection it is interesting to note that the cell walls of *Stictopora gracilis*, *Spencer*, present the same appearance, momentarily suggesting a graptolite.

PLATE VIII.

Fig. 1. *Acidaspis Ortoni, n. sp;* a head, anterior margin unknown.

Fig. 2. *Proetus determinatus, n sp;* a glabella with part of anterior border.

Fig. 3. *Proetus determinatus, n. sp;* a glabella, with attached border and palpebral lobe.

Fig. 4. *Phacops pulchellus, n. sp;* an associated pygidium.

Fig. 5. *Proetus* ————; a glabella with anterior border and palpebral lobe.

Fig. 6. *Illænus Daytonensis, Hall and Whitfield;* rostrum in position, sharp edged postero-lateral margins of movable cheeks broken off; a, a movable cheek, from Ludlow Falls.

Fig. 7. *Illænus Madisonianus, Whitfield;* a glabella, very doubtfully referred here.

Fig. 8. *Illænus Madisonianus, Whitfield;* pygidium, with paraboloid outline.

Fig. 9. *Illænus Madisonianus, Whitfield;* pygidium, somewhat broader.

Fig. 10. *Illænus Madisonianus, Whitfield;* pygidium, semi-circular, not paraboloid.

Fig. 11. A hypostoma, very doubtfully referred to some species of Illænus.

Fig. 12. *Calymene Vogdesi, n. sp;* head of type specimen.

Fig. 13. *Calymene Vogdesi, n. sp;* profile along the middle of the same.

Fig. 14. *Calymene Vogdesi, n. sp;* head of a younger specimen.

Fig. 15. *Calymene Vogdesi, n. sp;* profile along the middle of the same.

Fig. 16. *Calymene Vogdesi, n. sp;* characteristic pygidium.

Fig. 17. *Ceraurus* ————; a glabella.

Fig. 18. *Lichas breviceps, Hall;* a glabella, with part of a fixed cheek.

Fig. 19. *Lichas breviceps, Hall;* a hypostoma.

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III.

ON THE DETERMINATION OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FORCE.

BY L. E. AKINS.

The method I have used in the determination of H is the one used at the University of Glasgow. The attractive feature of the method is the simplicity with which the ratio of m to H, and the product of mH are determined, where m is the magnetic moment of a given bar magnet. The apparatus used is a small Bottomley magnetometer and a deflecting bar magnet.

The cut, which is exactly one half full size, fully illustrates the magnetometer, except that the needle needs a little explanation. The one I used consists of two bar magnets about eight-tenths centimetres long and one-tenth centimetre wide, and as thin as the steel can be conveniently worked. The magnets are fastened with shellac, like poles together, to the back of a small mirror and suspended by a single silk fiber as in the cut. I silver my own mirrors, using the short process given in Roscoe's Chemistry, Vol. II. With care in cleaning and by keeping the glass quite warm while the silver is being precipitated, a very good mirror can be obtained. The mirrors I used were small microscope covers five-tenths centimetres in diameter.

The first experiment is to find an expression for $\frac{m}{H}$ which is accomplished as follows. The magnetometer is set up so that its needle is in the magnetic meridian of the place and its centre directly over the point where a line, exactly at right angles to the N. and S. line, cuts that line. A very convenient arrangement for this consists of two boards, each eight inches wide, one five feet long, the other

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on, and deflections taken; then, *r. l. a. m. H.* meaning same as before, $\frac{\mathrm{m}}{\mathrm{H}} = (\mathrm{r}^2 + \mathrm{l}^2)^{3\text{-}2}\ \mathrm{Tan}\ a.$ (2)

The magnetometer is now removed, and the bar magnet suspended by a single fiber of silk, where the magnetometer stood. The ingenuity of the experimenter will best find a way for doing this. It is well to fasten a very small mirror to the suspension fiber, so that the period may be observed from the reflected light on the scale. The fiber in this case should be as long as possible to make the error due to its torsional rigidity as near a minimum as possible. If the fiber be twenty centimetres long, the error will be so near to zero as not to practically effect the result. The equation Mr. Gray gives for the determining of T in terms of m and H is $\frac{d^2 a}{dt^2} + \frac{\mathrm{m\ H}}{\mathrm{N}}\, a = 0$ where N is the moment of inertia of the vibrating system. The solution of this equation can be found in Williamson and Tarlton's Dynamics, art. 107.; or in Dynamics of a Particle by Tait and Steel, art. 88. From this $\mathrm{T} = 2\,\mathrm{II}\sqrt{\frac{\mathrm{N}}{\mathrm{m\ H}}}$ * For magnets one tenth centimetre in diameter $\mathrm{N} = \frac{\mathrm{W\ l}^2}{3}$ where W is the weight of the magnet in grammes. Therefore $\mathrm{m\ H} = \frac{4\ \mathrm{II}^2\ \mathrm{l}^2\ \mathrm{W}}{3\ \mathrm{T}^2}$ (3) Combining this with (1) $\mathrm{H}^2 = 8\text{-}3\,\frac{\mathrm{II}^2\ \mathrm{l}^2\ \mathrm{r\ W}}{\mathrm{T}^2\ (\mathrm{r}^2 - \mathrm{l}^2)^2\ \mathrm{Tan}\ a}$ and with (2) $\mathrm{H}^2 = 4\text{-}3\,\frac{\mathrm{II}^2\ \mathrm{l}^2\ \mathrm{W}}{(\mathrm{r}^2 + \mathrm{l}^2)^{3\text{-}2}\ \mathrm{T}^2\ \mathrm{Tan}\ a}$

The measurements should all be in the metric system and then the value of H is given in c. g. s. units. I find that magnets for deflectors made from No. 18 knitting needles and ten centimetres long give the best results. If wire of a larger diameter is used, a more complicated formula must be used, involving the moment of inertia of a right cylinder about an axis through its centre of gravity and perpendicular to its own axis. The length l is the measured half length of the bar magnet. Mr. Gray gives a method for determiniug the actual effective length of the magnet; but I have not used it. Corrections also might be made for atmospheric resistance to the vibrator, change of length due to change of temperature; but these are so very small that, for practical purposes, they may be neglected.

The angle $2a$ should be so small that $\mathrm{Tan}\ a = \frac{1}{2}\ \mathrm{Tan}\ 2\,a.$ This will avoid much labor in making computations.

As the mean of a considerable number of experiments I find for

H in my study the value .19707 c. g. s. units. Of course the value is always modified by the presence of iron, and I could not eliminate errors resulting from that.

The following from my results of Mar. 28 will help to illustrate the method used :

SIDE ON.

Magnet	Mar	Tan.2a	Tan. a	l	r	T	W	H
A	28	$\frac{19.5}{1000}$	.00975	5	35	4.16	.8765 gr.	.1989
B	28	$\frac{20.125}{1000}$	.01007	5	35	4.08	.8682 gr.	.1963
C	28	$\frac{13.875}{1000}$	.00694	5	35	4.706	.8745 gr.	.1987
D	28	$\frac{19.75}{1000}$	.00988	5	35	4.285	9255 gr.	.1953

For further explanation the student is referred to Mr. Gray's book. I make no claim to originality. I have only followed as nearly as possibile the directions given there. I have been so pleased with the method that I have thought others might be induced to try it.

---

*The symbol Pi is represented by II throughout.

IV.

LIST OF ALGÆ.

BY H. L. JONES.

The following list of Algæ is made up from specimens collected at the Licking Reservoir and from ponds in the vicinity of Granville. Only a very few of the most common species are here given, with the exception of the desmids, the list of which is somewhat more complete.

Spirogyra Weberi, Ktz.,

Spirogyra insignis, Ktz.,

Scenedesmus polymorphus, Wood,

Scenedesmus quadricauda, Breb.,

Pediastrum simplex, Meyer,

Pediastrum Ehrenbergii, A. Br.,

Pediastrum Boryanum, Turpin,

Pediastrum angulosum, Menegh.,

Cosmarium Brebissonii, Menegh.,

Cosmarium contractum, Kirch.,

Cosmarium Seelyanum, Wolle,

Cosmarium intermedium, Delp.,

Cosmarium Botrytis, Menegh.,

Cosmarium latum, Breb.,

Cosmarium Broomei, Thwaites,
Cosmarium orbiculatum, Ralfs,
Cosmarium Ralfsii, Breb.,
Cosmarium tinctum, Ralfs,
Cosmarium biretum, Breb.,
Micrasterias truncata, Ralfs,
Desmidium Swartzii, Ag.,
Sphaerozosma filiforme, Rab.,
Closterium moniliferum, Ehrb.,
Closterium Dianæ, Ehrb.,
Closterium parvulum, Naeg.,
Closterium strigosum, Ehrb.,
Closterium lineatum, Ehrb.,
Staurastrum polymorphum, Breb.,
Staurastrum pseudopachyrhynchum, Wolle,
Staurastrum inconspicuum, Nord.,
Staurastrum anatinum, Cooke and Wells,
Dociduum Trabecula, Naeg.,
Euastrum elegans, Breb.,
Euastrum rostratrum, Ralfs,

Ktz.—F. T. Kuetzing; Breb.—A. de Brebisson; A. Br.—Ale
Menegh.—J. Meneghini; Kirch.—O. Kirchner; Delp.—J. B. Delpo
C. A. Agardh; Naeg.—C. Nageli; Nord.—O. Nordstedt.

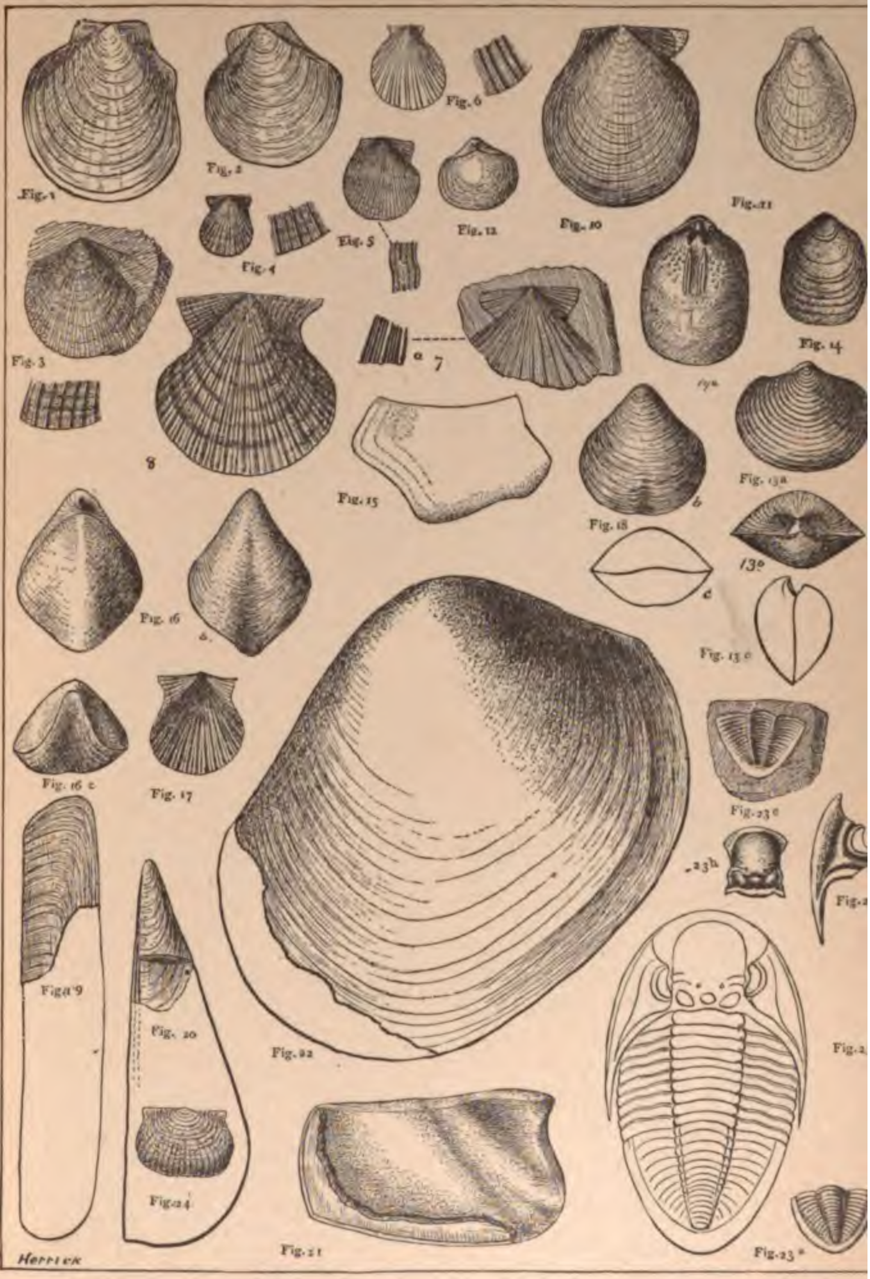
Fig. 1
Fig. 2
Fig. 6
Fig. 5
Fig. 12
Fig. 10
Fig. 11
Fig. 4
Fig. 3
a 7
8
Fig. 15
19a
Fig. 14
Fig. 18
b
Fig. 13a
13b
c
Fig. 13c
Fig. 16
b.
Fig. 16 c
Fig. 17
Fig. 23c
23b
Fig.
Fig. 9
Fig. 20
Fig. 22
Fig.
Fig. 24
Fig. 21
Fig. 23a
Herrick

PLATE I.

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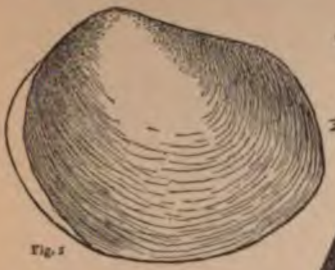

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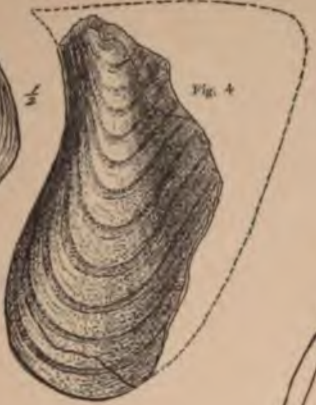


Fig. 4

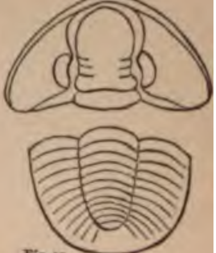


Fig. 11

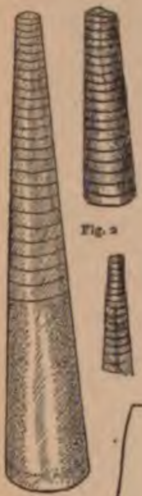
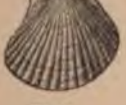


Fig. 2



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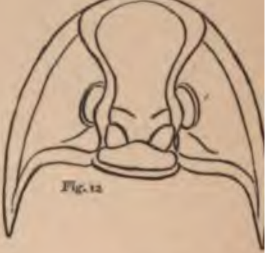

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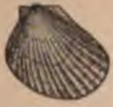


Fig. 3 A

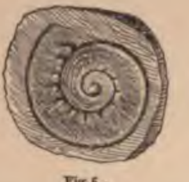


Fig. 5.

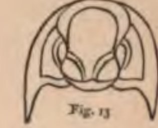


Fig. 13

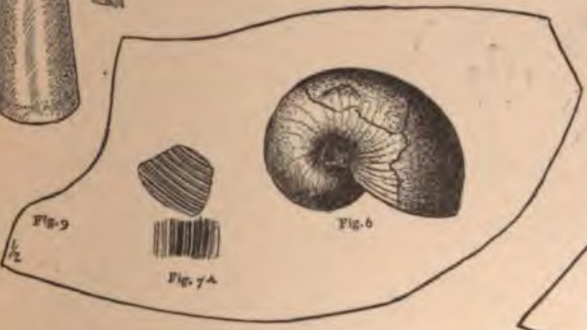
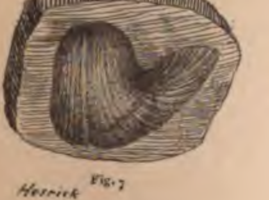


Fig. 9

Fig. 7 A

Fig. 6

Fig. 10.



Herrick Fig. 7

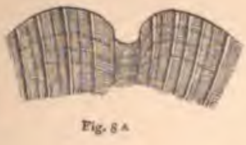


Fig. 8 A

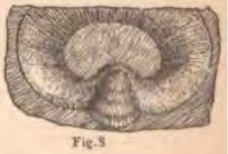


Fig. 8

PLATE V.

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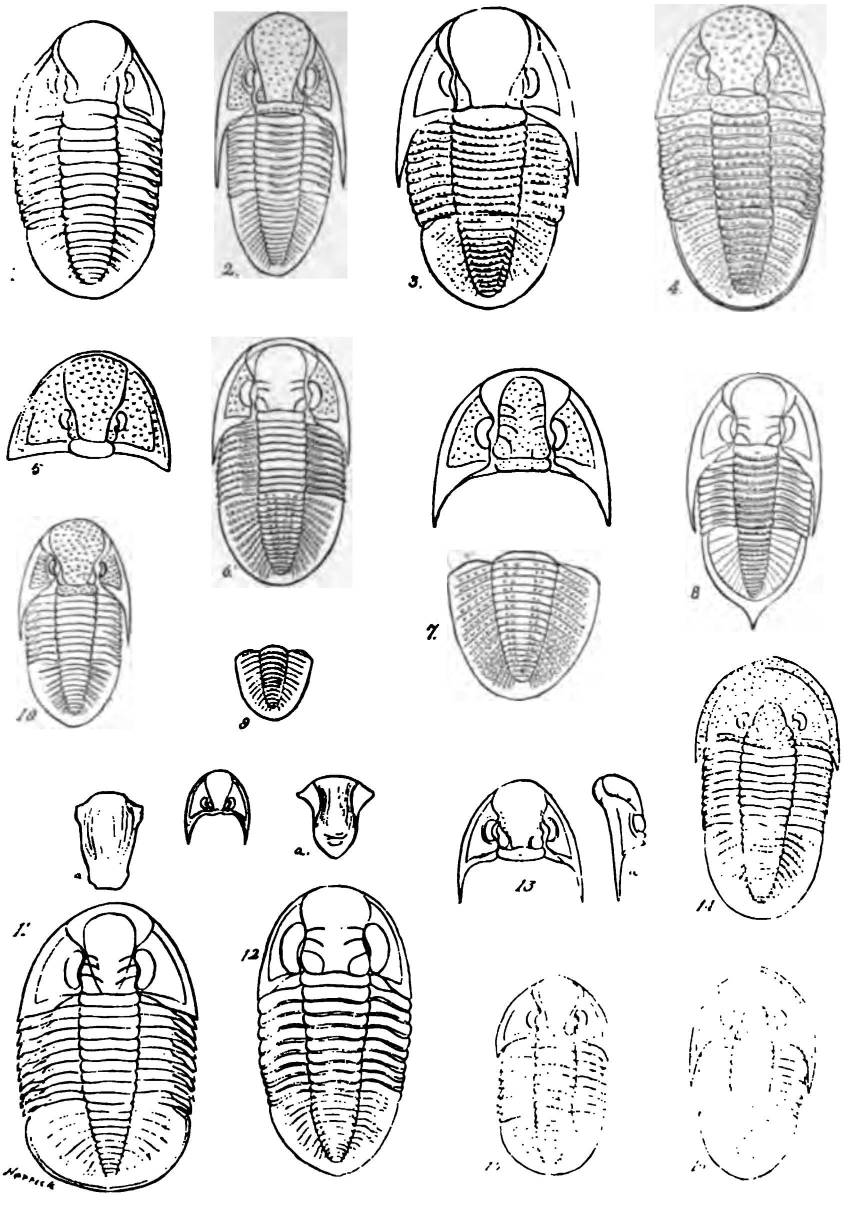

PLATE VI

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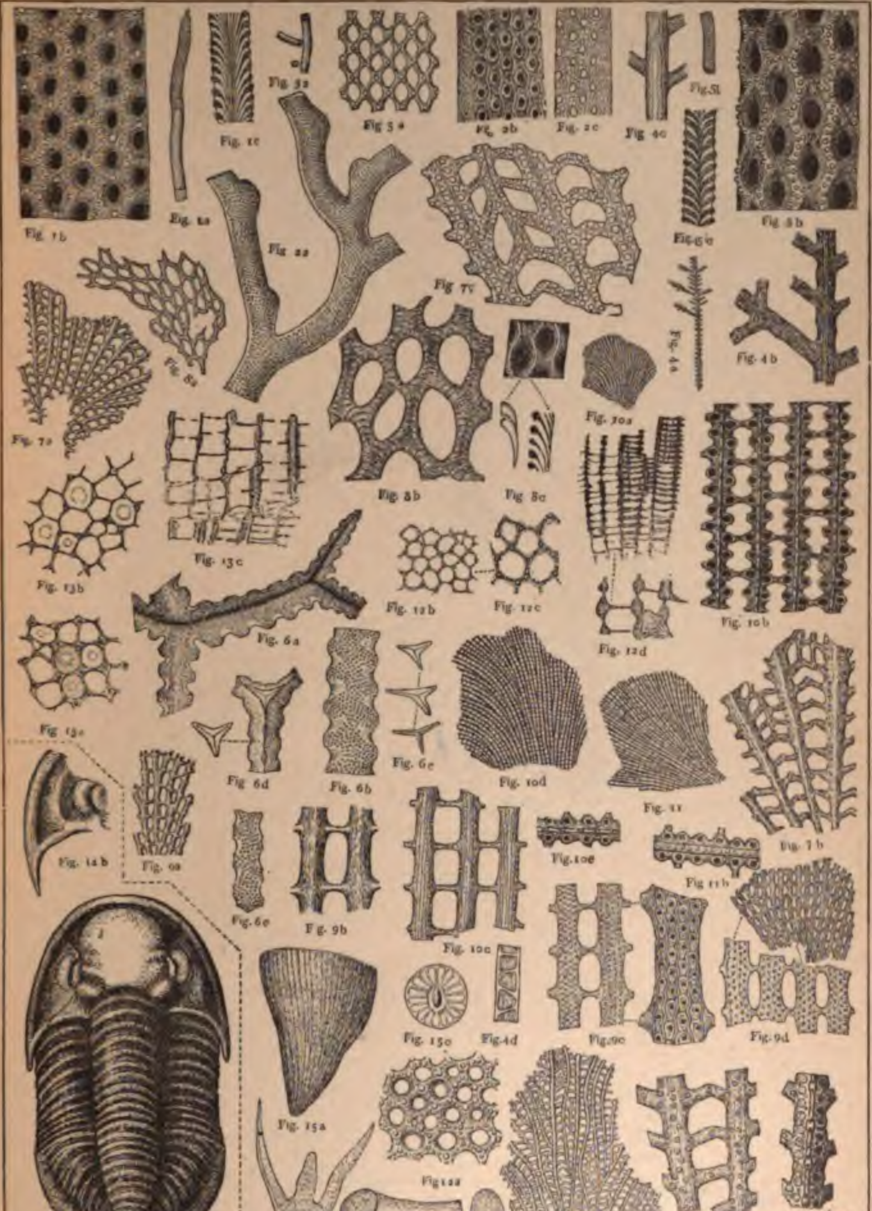
Fig. 1b
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Fig 3a
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Fig. 2b
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Fig 4c
Fig 5l
Fig 5b
Fig 2a
Fig 7c
Fig 5b
Fig 4a
Fig 4b
Fig 8a
Fig. 7a
Fig. 8b
Fig 8c
Fig. 10a
Fig. 13c
Fig. 13b
Fig. 12b
Fig. 12c
Fig. 12d
Fig. 10b
Fig. 6a
Fig 13a
Fig 6d
Fig. 6b
Fig. 6c
Fig. 10d
Fig. 11
Fig. 7b
Fig. 14b
Fig. 9a
Fig. 6e
Fig. 9b
Fig. 10c
Fig. 10e
Fig 11b
Fig. 15c
Fig. 4d
Fig. 9c
Fig. 9d
Fig. 15a
Fig 12a
Fig 16b
Fig. 16c
HERRICK
Fig 12a
Fig. 15b
Fig 1a
Fig. 10a
Aug. F. Foerste

PLATE VII.

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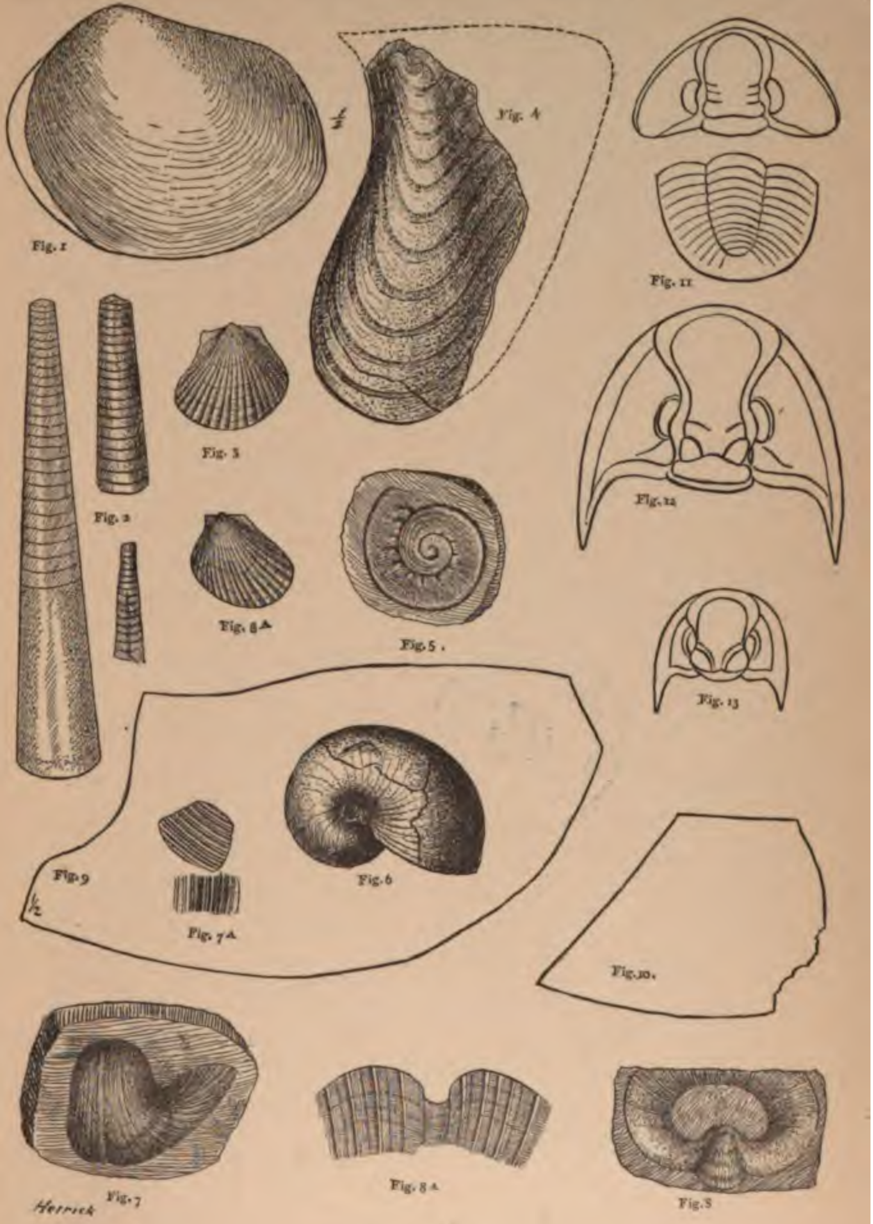
½
Fig. 4
Fig. 1
Fig. 11
Fig. 3
Fig. 2
Fig. 12
Fig. 8A
Fig. 5.
Fig. 13
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Fig. 6
Fig. 7A
Fig. 10.
Fig. 8A
Fig. 8
Herrick
Fig. 7

PLATE V.

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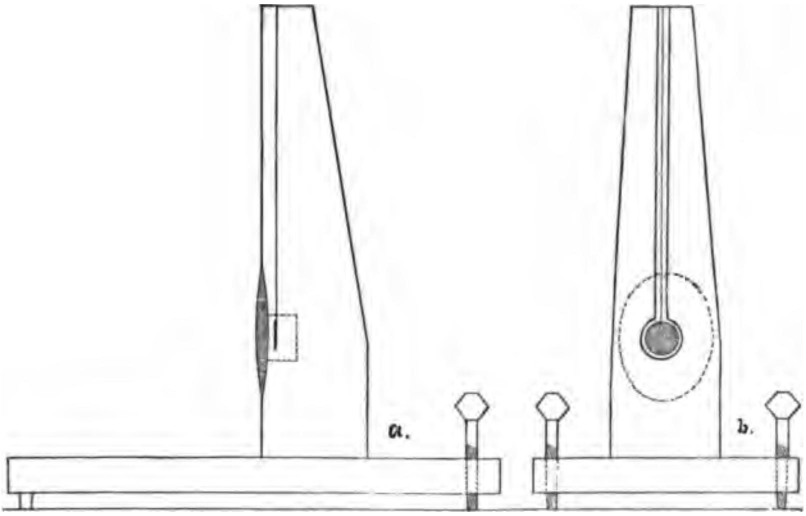

Side View. *End View.*

MAGNETOMETER.

PLATE IX.

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BULLETIN

OF THE

SCIENTIFIC LABORATORIES

OF

DENISON UNIVERSITY,

EDITED BY

C. L. HERRICK, DEP'T. OF GEOL. AND NAT. HISTORY,

AND

A. D. COLE, DEP'T. OF CHEMISTRY AND PHYSICS.

VOL. II, PART 2.

GRANVILLE, OHIO, APRIL, 1887.

V.

GEOLOGY AND LITHOLOGY OF MICHIPICOTEN BAY.

RESULTS OF THE SUMMER LABORATORY SESSION OF 1886.

C. L. Herrick, W. G. Tight, and H. L. Jones.

[*Read before the Denison Scientific Association, April* 23, 1886.]

The excursion was undertaken with a view primarily to the enlargement of the working series of crystalline rocks in our cabinet and in the hope of affording a useful supplement to the class-work in lithology, though it fell to the lot of but few of the class to participate in it. It is hoped that these peripatetic summer training classes may become a valuable adjunct to the regular work so long, at least, as we have, as now, numbers who expect to work as scientific specialists.

The party left the Sault Ste. Marie, on the little steamer Remora, and arrived at the fishing station near the mouth of the Dog River, in Michipicoten Bay, at 4 o'clock in the afternoon when, by the kindness of the agent, we were promptly transported to our permanent camping station on the left bank of the Dog River at its mouth. Here a temporary laboratory was located, and by means of oars and sail much of the adjacent coast was carefully studied.

Those not particularly familiar with recent geological literature may ask why this special locality was chosen for the summer's work and what is the nature of the problems whose solution was sought. To properly answer these questions would be to review in great part the writings of most of our leading geologists during a period of many years, especially those of Canada, Michigan and Wisconsin. Such an extended review is, however, rendered unnecessary by the fact that

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C. L. Herrick, W. G. Tight, and H. L. Jones.

[*Read before the Denison Scientific Association, April* 23, 1886.]

The excursion was undertaken with a view primarily to the enlargement of the working series of crystalline rocks in our cabinet and in the hope of affording a useful supplement to the class-work in lithology, though it fell to the lot of but few of the class to participate in it. It is hoped that these peripatetic summer training classes may become a valuable adjunct to the regular work so long, at least, as we have, as now, numbers who expect to work as scientific specialists.

The party left the Sault Ste. Marie, on the little steamer Remora, and arrived at the fishing station near the mouth of the Dog River, in Michipicoten Bay, at 4 o'clock in the afternoon when, by the kindness of the agent, we were promptly transported to our permanent camping station on the left bank of the Dog River at its mouth. Here a temporary laboratory was located, and by means of oars and sail much of the adjacent coast was carefully studied.

Those not particularly familiar with recent geological literature may ask why this special locality was chosen for the summer's work and what is the nature of the problems whose solution was sought. To properly answer these questions would be to review in great part the writings of most of our leading geologists during a period of many years, especially those of Canada, Michigan and Wisconsin. Such an extended review is, however, rendered unnecessary by the fact that

several of the recent writers on the geology of Lake Superior have given such collations and discussions from their several points of view, notably Wadsworth, in "The Azoic System and its subdivisions", 1884, and Irving, in his "Copper-bearing rocks of L. Superior", 1885. Recent discussions may also be found in the Annual Reports of Minnesota. In the region in question the geological relations appear to be relatively simple, but at the same time so intimately associated with the more intricate regions now chiefly under discussion as to make any conclusions which can be reached of considerable value.

In general then, the region northward from L. Superior is a part of the great V-shaped area of crystalline rocks classed as Azoic and usually grouped in two great series, the one largely composed of gneisses and granites and called Lawrentian, and the other, assumed to be higher (and hence later) composed of crystalline slates and schists. This whole series is supposed to consist of altered sediments, but with an unconformity between the two groups. The evidences of life are restricted to those furnished by the exceedingly problematical Eozoon and the presence of graphite and iron. The original name given to both these members was the term Azoic, applied by Foster and Whitney, in 1850. Whitney and Wadsworth vigorously assert that there exists no reason for changing this name (as to Archean) or subdividing the series (into Lawrentian and Huronian). The Canadian geologists claim that the Huronian schists are constantly unconformable to the underlying Lawrentian and frequently contain pebbles from it. To this Wadsworth and Whitney reply that there is a lack of observation to substantiate the claim of unconformability and that the pebbles are high in the series of the Huronian and not in any sense basement conglomerates. At page 557 of the "Azoic System," these authors seem to imply that the Huronian conglomerates are formed by the imbedding of matter ejected in a fragmental state in a detrital magma.

In the region under consideration a further difference of opinion seems to prevail. Irving, in the map of L. Superior, given in his valuable report on the "Copper-bearing Rocks," marks all the granitic areas as Lawrentian and the schists as Huronian, while the Canadian geological map indicates all the granite areas near the lake and associated with the schists as eruptive, although a region to the north is covered with the Lawrentian. In the sequel the evidence which leads us to accept the conclusions of the Canadian geologists as to this particular region, is reviewed in detail so far as our material warrants.

The most detailed account of the relations between the schists and granite seems to be that of McFarlane, who says: "The manner in which these Huronian rocks adjoin those of the Lawrentian series may be observed on the north shore between Michipicoten Harbor and Island. I paid some attention to that point of junction which lies to the west of Eagle R., the precipitous cliffs to the east of which consist principally of diabase schist and greenstone slate. A few miles to the west of these cliffs and at a point bearing N. 29°, 5° E., from the east end of Michipicoten Island, the Lawrentian granite is penetrated by enormous dykes of dense basaltic greenstone (having the peculiar doleritic glitter when fractured) which contain masses of granite. This greenstone is also seen in large masses, which can scarcely be called dykes, overlying the granite and enclosing huge masses of that rock, one of which I observed to be cut by a small vein of the greenstone. From this point to the Eagle R. these two rocks alternately occupy the space along the shore, seldom in such a manner as to show any regular superposition of the greenstone on the granite, but almost always more or less in contact with each other. The greenstone however, becomes more frequent towards the east and at Eagle R. it has almost replaced the granite, and assumed a lighter color, and an irregularly schistose structure. The strike of these schists is at places quite inconstant; they wind in all directions, and what appear at first sight to be quartz veins accompany their contortions. On closer inspection, however, of the largest of these, they are seen to be of granite, but whether twisted fragments of that rock or really veins in it, is at first glance very uncertain. * * * Although they are seldom or never angular they can scarcely be regarded otherwise than as fragments whose shape has been modified by contact with the greenstone. * * * Either the granite forms veins, penetrating the schistose greenstones, in which case the latter are the older rocks; or it is in the form of contorted fragments, in which case the enclosing rock may be of eruptive origin. The latter supposition seems to be most in harmony with the facts stated." (Rep. Progress 1863–66.) Commenting on this account Whitney and Wadsworth remarked: "It seems almost incredible that a geologist, who professed to be a lithologist, should have been unable to ascertain the relations and relative age of these rocks when so many excellent exposures were observed, as he states. His observations show clearly that both formations here are eruptive and of the same geological age." (Azoic System, p. 346.)

2. Rocks having the composition of mica-diorite or diorite, but containing much calcite. Rocks of this group tend to assimilate closely in appearance and structure to the schists in contact and suggest the possibility of their having been the products of metamorphism of the schists themselves again altered by slow metasomatic changes. A circumstance greatly favoring this theory is the fact that the dykes in the underlying granite are always diabases so far as observed while the diorites are very frequent in the schists. That the contact action of the granites was amply sufficient to produce such fusion is abundantly demonstrable.

4. Orthoclase and quartz-orthoclase felsite-porphyries occurring under two conditions, but generally in such a way as to suggest an extraneous origin of the porphyritic ingredients; first, contacts of conglomerates with dykes of diabase or of diorite, second, interbedded layers in the schist with adjacent alteration and veiny structure. We incline to the belief that the greater part of the porphyry can be traced directly to metamorphism in such conglomerates induced by adjacent later eruptives.

Having thus briefly disposed of the two older groups we will now consider the relation of the third or Keweenawan series to these. The direction of the strike and dip of these series on Michipicoten Island and Capes Choyye and Cargantua, furnish the only data on which to base our conclusions. The strike on Michipicoten Island appears to be in general a little N. of E., varying from the E. end of the island to the W. end, toward the west end becoming more northerly. At cape Choyye the strike seems to be in a direction a little W. of S., while at cape Cargantua it extends in almost a southern direction, varying a little to E. This would seem to indicate that the older rocks upon which the Keweenawan rests formed a synclinal with its axis in a N. E. direction. The position of the granite rocks on either side of this axis would indicate a synclinal rather than an eroded anticlinal, as is the general rule. Also the fact that the Keweenawan is deposited within the basin itself and its margins abutt against the high cliffs of the eroded older rocks. The relation of the basement conglomerates exposed at cape Choyye to the older series will be discussed upon a later page. The most complete discussion of the Keweenawan is that of Prof. Irving, in his monograph of the Copper-bearing Rocks of Lake Superior. We may now proceed at once to a

Description of the Rocks of Michipicoten Bay.

It has been thought best to present these descriptions in about the order in which they were examined by us, in order to place the reader as nearly as possible at the same standpoint in regard to the questions under discussion.

At the mouth of Dog river and extending along the coast for some miles is No. 1001. *Typical chloritic slate*, strike S. 32° E., dip 80° N. E. Very fissile and somewhat unctuous. Under the microscope, the magma is close-grained, with much chlorite, irregular scales of biotite, large irregular grains of calcite, occasional fragments of orthoclase, fewer quartz grains, numerous crystalline grains of magnetite, and some irridescent white scales which may be talc. The calcite, which is characteristic of most of these schists, is here frequently granularly decomposed in the centre of the grain. It is easily recognized even in small grains by its irridescence and in larger ones by the rhombohedral cleavage and twins.

Nos. 1005–1007. Same slate as No. 1001, but modified by contact with dyke of No. 1004. The surfaces of the lamellæ are covered with wavy ridges arranged in "cohesion figures." The dark ingredients are collected in zones of varying width. Grains of orthoclase and plagioclase occur as well as quartz, which last in some cases is surrounded by a zone of radially arranged fibres or plates of chlorite. The calcite is also collected into zones. In one place (No. 1007) in proximity to a quartz vein the rock is largely made up of rather regular though decomposing feldspar, chiefly orthoclase in Carlsbad twins. The contact with the quartz is sharp, but the latter is permeated at the edges by calcite and into it are fused iron globules from the schist. Both these circumstances give evidence of high temperature during the formation of the vein.

At the point one half mile east of Dog river is a wide band of conglomerate (No. 1023 see beyond) passing which, we encounter broad bands of yellowish felsite-porphyry and obliquely arranged lenticular masses and strings of a similar character (Fig. 5, Plate XI.)

No. 1008 is a specimen from the lenticular masses and consists of an exceedingly fine-grained felsitic magma, containing large rounded grains or nearly perfect crystals of quartz and feldspar, (Plate XI, Fig. 2.) The grains of quartz, though greatly rounded, appear to have been doubly terminated crystals, while the feldspar, which is nearly all or-

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No. 1009, from the bands, is essentially similar, but is much finer-grained and has fewer and smaller porphyritic ingredients. There are mica rosettes and groups of magnetite, pyrite, apatite and other accessories, as well as veins of calcite.

No. 1011. Chloritic schist one-half to three-fourths of a mile N. E. of Dog river. It is greatly contorted, unctuous, containing large quantities of calcite in the form of veins which conform to the contortion. Microscopically it appears to be composed of a ground mass of chlorite scales which when reduced to very thin sections lose their polarization colors and pleochroism. This ground mass is filled with large crystals of much altered orthoclase, which have a tendency to aggregate at 90° to axis c. The titanic iron shows all the gradations to titanite. Large calcite grains showing characteristic cleavage in three directions, with banded structure. The crystals of apatite penetrate all the ingredients of the rock. The rock appears to be much altered from the influence of the interpenetrating diabase dykes. Here as in other places it seems as if the interpenetrating dykes coming through the primitive schists had fused the lower portions which oozed up along the sides of the dyke and in cooling formed the more coarsely crystalline rock No. 1012. (Plate XII, Figs. 1, 2, and 3.)

No. 1012. Dark gray, coarse grained, unevenly fracturing rock, intersected in all directions by veins of various minerals. Microscopically it appears coarsely crystalline, with orthoclase and plagioclase magma. The rock contains a considerable amount of biotite, some calcite and a very few grains of hematite, with crystals of apatite scattered through it sparingly. It appears as if this rock was the slowly cooled product of the fused lower portion of the schists in which mica and plagioclase have crystalized out. This all, apparently, through the influence of the dyke which comes up through this boss and forms No. 1013.

No. 1013. A fine grained dark rock presenting all the characters of a typical diabase. The line of contact with No. 12 is very sharply marked.

Next, passing up Dog river about one-eighth of a mile from its mouth, we encountered a large dyke 15–20 feet in width, No. 1017, which in microscopic section presents all the characters of a typical diabase similar to the other dark, fine-grained dykes. Its feldspars consist of oligoclase with an angle of about 26° and labradorite with an angle of about 48°. Some magnetite, otherwise very free from accessory ingredients. Adjacent to this dyke is the indurated slate forming No. 1018, finely crystalline, containing large quantities of brown mica in scales in O plane, also many irregular grains (Plate XII, Fig. 5A), and grains of magnetite broken up into fine powder, also a few calcite grains, showing characteristic cleavage. The mica appears to be decomposing to chlorite, forming a chlorite and quartz basis. Pseudomorph crystals of chlorite after mica are seen (Plate XII, Fig. 5B.) Passing farther up the river the slate becomes porpyritic for a considerable thickness.

No. 1019 is a sample of this porphyry. It has a very fine quartz magma, with brown mica. The orthoclase crystals have more or less regular crystalline outlines and its general appearance is strikingly similar to that of the pebbles in the conglomerate No. 1023. In close contact with this porphyry is No. 1019a, a dark very fine grained typical diabase. Its relation to No. 1019 is shown in Plate XI, Fig. 6. It appears from the relations as if the porphyry (No. 1019) was once continuous with the conglomerate No. 1023, which is found a little farther up the river, but has lost its conglomeritic structure and suffered the complete fusion of the pebbles and schist through the influence of this dyke No 1019a.

No. 1023 is the band of conglomerate at lower Denison Falls, where it is from 39–75 feet in width. Its ground mass, which is nearly similar to the adjacent schist, is filled with water-worn pebbles of a porphyritic rock No. 1023a. (See Plate XII, Fig. 9.)

No. 1023a. These pebbles have a sharp outline and can be perfectly separated from the ground mass. They show unmistakable evidence of the action of water in rounding their corners and angles before their deposition. They also show the jointage planes of the primitive rocks from which they were derived. Their general external appearance is about the same, but under microscopic examination of a large number of slides it is clearly shown that they consist of two distinct rock species. This distinction is well marked, for there is shown no gradation from one to the other, even in pebbles which are only an inch or two apart and which must have been subjected to the same agencies of metamorphism. One of these species presents all the characters of a typical granite with much quartz and orthoclase and few accessories. There is some pyrite, probably secondary. The orthoclase is much altered and gives aggregate polarization. The quartz grains are filled with numerous fracture lines and are rendered almost cloudy with microlitic inclusions, both apparently the result of intense heat and pressure. The other variety is unmistakably porphyry, with an almost irresolvable ground mass of quartz filled with large crystals of orthoclase, with now and then a large grain of quartz. These pebbles also appear to be very much altered from the action of heat. The orthoclase still can be determined by its aggregate polarization, crystalline outline and perpendicular extinction. In microscopic characters this rocks resembles very closely the porphyritic phase of the schist further down the river. A mile or so above the falls is a shining, fissile chloritic schist (No. 1027) which under the microscope proves to have a very uniform ground-mass of quartz and chlorite with a very little brown mica and numerous and regularly distributed minute unterminated crystals of an orthorhombic mineral with optical characters of staurolite. Much of the schist is of a highly metamorphic character, but preserves the usual strike and dip.

Nos. 1016, 1029, 1031, and 1036 are various phases of gneiss extending from a point one-half a mile east of the union of Mountain river with Dog river, in the line of strike, to intersect the coast several miles northeast of the mouth of the latter. This series consists of several bands of varying width and texture interstratified and conformable with the schists. No. 1016 occurs along the shore near the Terraces, forming high bluffs. It is a very fine-grained dark gneiss, with obvious bands of flesh-colored feldspar. Microscopically the mass of the rock is composed of much green muscovite mica, considerable epidote in zones (recognized by its bright yellow color,) relatively large amounts of oligoclase and decomposing feldspathic ingredient (orthoclase). There are innumerable needles of a transparent substance apparently derived from the mica. Some calcite is probably derived from the same source. Very little quartz is present.

No. 1036 is identical with No. 1016 and is from an adjacent exposure, but it is nearly schistose and the section exhibits a few veins of amorphous substance full of minute needles (sillimanite ?) like those above mentioned.

No. 1031 is the same gneiss where it intersects Mountain river. Here it is somewhat coarsely granular, containing more orthoclase and biotite mica. There is some (perhaps secondary) quartz in the confused portion. The transition to the schist is here very readily seen, there being no unconformity.

No. 1029 is a phase of No. 1031, just at contact with the schist and partakes of its characters. It has biotite in large quantities in conspicuous masses surrounded by irregularly disposed augite grains. The most of the remainder being plagioclase and orthoclase, with some quartz and an occasional large grain of calcite. The augite is very brilliantly polarized, but chiefly in grains or much broken crystals.

From the above it may be gathered that these gneissic rocks form really an integral part of the schists, being more highly metamorphosed than they. We incline to regard them as the axial part of the fold, the strata repeating to all appearances on either side, as indicated in our diagram. The relation of the strata is such as to permit us to consider the schist conglomerate a true basement conglomerate.

Passing beyond the gneiss the same series seems to be repeated in reverse order, though more careful examination is needed on this point.

No. 1037 resembles closely 1009 and is followed by No. 1038, which is identified with the conglomerate No. 1023. This is followed by schists. The contact of these schists with the granite is very suggestive. At a little distance from the contact, the schist (No. 1045) is a shining green chloritic mica schist, with light specks scattered through it. Under the microscope it is seen that the green mineral is arranged in wavy bands separating aggregates of quartz in a finely granular condition with large porphyritic brown grains, seemingly aggregates. Close examination shows however that the brown granular appearance masks calcite, with its cleavage and irridescence, and a comparison with the part more nearly adjacent to the granite shows the brown grains to have been feldspar from the latter.

No. 1046 is on the granite side of the contact and is an altered granite, having the quartz and feldspar imbedded porphyritically in a magma like that of the schist. The orthoclase is much altered by heat and the crystals are margined by calcite. The quartz is less fractured than in 1045, but on the whole the two are much alike. The original crystals of biotite (?) are broken up and greatly altered. The unaltered granite (No. 1042) is very coarsely granular and is perforated by many diabase dykes having the same general strike as in the schist. The granite continues to Little Bear river and thence to Dore′ river, to the east of which a chloritic slate appears. The strike is S. 50° E. with a dip toward the southwest of about 45°, though the strata are very tortuous and embrace included masses. The contact with the granite is here as elsewhere evidence of the eruptive nature of the granite. Irving's map does not correctly represent the distribution of the granite in this bay. Gros Cap is the promontory west of Michipicoten harbor and is said to bear hematite veins. Bell says it is composed of slaty diorite, though the only rock seen by us was a tough silicious chlorite schist. At Michipicoten river the rocks are said to be dark hornblendic mica schist.

Leaving Gros Cap we crossed the entrance to Michipicoten harbor and encamped upon a narrow beach nearly directly south of the point. The rock here is strongly tortuous and confused. Much of the rock is porphyritic in a grayish-green base, while other portions are of dense close texture and uniformly micro-crystalline. In one place beneath the water the porphyritic rock could be seen to contain large rounded masses of a different color, often a foot or more in diameter. These were supposed to be similar to the conglomerate pebbles of the west side. As typical of much of the unporphyritic rock of this shore we select No. 1068, which appears to the eye like a moderately fine-grained diorite. The thin section shows it to have undergone great alteration. The greater part of the field is made up of elongated unterminated fibrous crystals, lying at all angles and frayed out at the ends. These are of a pale green color and scarcely pleochroic. The polarization colors are very brilliant, like those of tremolite. In cross section two sets of cleavage lines, with an apparent angle of 120-130° appear, while the longitudinal cleavage lines are frequently wavy. The twins are numerous and in the plane i-i, and the extinction angle $c : \mathfrak{c} =$ nearly exactly 15°. This combination of characters is hard to understand. The absence of pleochroism and brilliant polarization indicate a monoclinic augite, but the extinction angle, cleavage, and habit are like hornblende. This is, therefore, a decomposing hornblende like uralite in general appearance and like actinolite in characters. The iron has nearly disappeared from the whole rock, a few scales of hematite being found in the hornblende.

The remaining ingredients of the diorite, with the exception of the rather small amount of quartz, are more completely altered. The place of the plagioclase is taken by an opaque white amorphous substance and the interstices are filled with granular light material. A few crystals of decayed augite are seen, which have large quantities of iron in scales and grains. Here and there grains of calcite indicate where some of the decomposition products have gone. There are exposed a few interesting masses of ilmenite, in which the hexagonal plates are matted obliquely, which show under the microscope the characteristic bronzy reflection.

No. 1064 is essentially similar. It is a very tough, homogeneous, greenish-grey rock. The actinolite is in the condition described above and the accessories are ilmenite, calcite, and apatite. It presents to the eye the appearance of a fine-grained diorite, altering to serpentine. Irregular bands of a lighter colored rock occur in this mass. Such a specimen is No. 1065, which is a confused mass of finely granular material in which quartz, calcite and chlorite can be identified. Strings or veins of calcite are abundant, and scattered through the magma are many dark grains, the centres of which are generally filled by a single crystal of secondary calcite.

No. 1066. This is the porphyritic phase before spoken of, which also contains the larger pebbles. Here and there in the section are large rounded grains of quartz, broken and intersected by the finely granular magma. The latter is not essentially different from the basis of 1065, but is crowded with rounded grains of oligoclase. Grains of secondary calcite and veins of the same, also pyrite and perhaps titanite are seen in the slide. It would appear that the magma is full of minute scales of chlorite. (Plate X, Fig. 2.)

The only explanation suggested for the curious condition of the rock here is that the metamorphism was excessive and resulted in a thorough suffusion of the original slate with intrusive matter as well as pasty portions of the adjacent sediments, reducing all to a somewhat homogeneous character. The conglomeritic phases of the slate being rendered pasty, the pebbles were at first unaffected and were intruded upon by the more fluid matter below. They were subjected to more violent flowage by reason of the obstinate pebbles during which the ingredients of the pebbles were partly set free and, although the magma was in part melted, the larger crystals remained dispersed in the magma in the corroded condition already described. The calcite and chlorite date from later periods.

At this point are a number of trap dykes, but the extreme point (Burnt Point?) is made up of granite, which continues to the mouth of Riviere de la Vieille. Just southwest of the river are precipitous cliffs, 600-800 feet high, made up of the highly metamorphic equivalent of the schist. Here at places the granite appears beneath the slate, which is unconformable and tortuous, without obvious stratification. The granite rises only a few feet above the water's edge in undulations and seems to have thoroughly fused the superincumbent schist at contact. A few miles further south, toward cape Choyye, the high bluffs recede from the shore, leaving the point composed of Keweenaw conglomerate and sandstone, which laps out near the water's edge at a slight inclination.

No. 1074 is a specimen of the schist taken near the underlying granite and is a greenish, irregularly fissile rock, completely checked up by joints and so altered and veiny as to act as an aggregate with much chlorite.

No. 1075, taken near cape Choyye, is an irregularly lamellated mica schist. The section shows much brown mica and quartz, some apatite, magnetite, pyrite, and scattered porphyritic more or less quadrangular grains appearing like completely decomposed feldspar. Although dip and strike, as taken, were dip 60°, strike S. 10° W., we rather incline to believe that this is the same rock as that on the west side of the bay, with a strike which might bring it hither.

Returning to Dog river, we proceeded westward for about six miles to near Eagle river, a small trout brook near the western limit of the bay. Here are precipitous cliffs nearly 800 feet high. The rock here consists of much altered highly crystalline schists, varying from green to brown (No. 1049-1049a). The mica is largely altered to chlorite in the green, while it is reduced to a powder in the brown and mixed with hematite. Both contain very large quantities of calcite, as a product of alteration of mica no doubt. These rocks contain much quartz. The strike is E.S.E., *i. e.* much more nearly east than farther northeast, and the dip only about 45°. Here in many places diorite lies interbedded between the strata of schist. This diorite is composed of the same twinned hornblende, mentioned at the east side of the harbor, but although it is superficially identical it differs in retaining strong pleochroism. The extinction angle and general appearance of the section, otherwise is identical. Here, too, the adjacent schist has assimilated itself to it most remarkably in general appearance, though a glance at a section shows it to be of a quite distinct character. It is really an *altered mica schist* (!) consisting of quartz, chlorite, much calcite and iron salts. This fact that certain eruptives have the power to assimilate the adjacent rocks so closely in external appearance as to defy recognition, while not altering the real nature of the rock, needs to be constantly borne in mind by field-geologists. These rocks, classed as greenstone slates and considered as eruptive by previous writers, can with care be readily separated into interbedded sedimentaries and eruptives. A succession of such dykes is seen east of Eagle river. West of Eagle river, especially on the jutting point referred to by McFarlane, the schist suffers the extreme of metamorphism, being twisted and gnarled in every conceivable way, at the same time seggregating various minerals in pockets and lenticular masses. Veins of granite perforate the schist and include it in irregular masses. The effect of such intrusive action is here well seen. The fragments of schist so inclosed are angular and though often fused into the granite, never permit comparison with the Dog river conglomerate. A direct comparison of this sort may bring out relations hard to verbally explain. The contact samples show much epidote which forms zones at the contact, veins in the schist, or replaces the hornblende in the granite. At this point is this immense dyke No. 1056.

No. 1058 is schist at the contact and consists almost entirely of epidote containing strings and fragments of the aphanitic margin of 1056. Westward the granite constantly encroaches on the schist, which is here a typical mica schist of fine texture.

The diabases, as before stated, are exceedingly monotonous in composition and structure. A considerable range of variation in the relative size of the ingredients is the chief divergence. They never carry an appreciable amount of olivine and the feldspars are either labradorite or labradorite and oligoclase, the former with brilliant polarization colors and distinct outlines.

No. 1056 may be taken as a type of the whole series. This is especially interesting as being the dyke northeast of Michipicoten island, called, by McFarlane, doleryte and considered by him and by Wadsworth after him, as one of the sources of the schist. This is grains of augite much broken up, always makes up a considerable per cent. of the rocks. They also carry quite a large amount of suffused iron.

On the southwest corner of the island, rising above the water's edge several feet, occurs a fine-grained conglomerate with small, sharply angular grains. Embedded in this are large boulders from one to twelve inches in size, of several different kinds. The question of the origin of these boulders becomes of the greatest value in establishing the relations of the different series. One of the most numerous is a granite, quite close-grained, light colored, containing somewhat altered white mica, orthoclase much changed, but still retaining its form, and quartz. There are no accessories present. These boulders have all been rounded by the action of water.

No. 1087 (Plate XIII, Fig. 2.) is from a typical mica schist of a light gray color, dotted all over by minute black crystals, giving it somewhat of a salt and pepper color. Microscopically the rock is seen to have a cloudy gray magma, in which are scattered very profusely small fragments of quartz. Large scales of biotite mica, permeated in all directions by smaller scales of the same, make up the remaining ingredients of the rock. Much of the mica is changed to chlorite. Comparing this specimen with No. 1051, a mica schist from the high cliffs, eight miles west from Dog river, on the main land, we find that they are almost identical in appearance and composition. Their color in the hand sample is the same as well as all of their macroscopic characteristics. Under the microscope we find the same similarities. The magma differs slightly, but it is very similar in both. The size and relative amount of quartz grains in the two are the same. The mica in No. 1051 is more altered and is not aggregated into such peculiar masses. Perhaps the most noticeable difference is the presence of a few small crystals of triclinic feldspar in No. 1051, but this can be explained by the proximity of the eruptive No. 1050.

Another interesting example is a boulder of mica diorite which is also common in the conglomerate. The plagioclase occurs as very numerous small elongated crystals, permeating the section in all directions. These have been slightly altered, but can be readily identified. The mica has for the most part disappeared, chlorite taking its place. This rock can also be readily referred to the igneous form, No. 1050, which occurs at the same cliffs, interbedded with the schists. As in the preceeding case the chief differences lie in the de-

Fig. 6.) The porphyritic grains are of plagioclase with scattered augite. It is thought that much of the granular magma is augitic. The ilmenite is altered in many places to titanic iron.

In discussing the Keweenaw rocks as exposed on Michipicoten island, cape Choyye and cape Cargantua, we shall describe only enough to give a clear idea of the relations of this series to the older Lawrentian and Huronian, as found in this region. We may consider these rocks under two heads; first, the eruptive igneous, including all the diabases, amygdaloids, pseud-amygdaloids and perhaps the porphyries; second, the sedimentary and metamorphic. The former might be considered the result of a single series of overflows closely related. The cooling of these, taking place under different conditions, as in the presence of water, superheated steam, under great pressure or otherwise, must of necessity produce many different forms of the same overflow. Only those whose structure is in some way characteristic, are here described.

No. 1077 (Plate XIII, Fig. 3.) occurs on the south shore of Michipicoten island, forming the most of the islands along the shore. It is filled with vein matter, principally of quartz and agate and is also somewhat amygdaloidal. The color is black, with almost a metallic lustre. An uneven fracture and exceedingly tough. The specific gravity is 2.76. Under the microscope the rock is seen to be completely crystalline. Oligoclase makes up a great portion of the section, occurring in long, fine crystals, generally twinned. Rounded grains of augite are scattered irregularly through the mass. Here and there a crystal of orthoclase is present, but much altered. A very peculiar kind of grains, evidently suffused with iron of a bright yellow color, without polarization or pleochroism, filled with inclusions, probably of gas, with concentric lines running through them, is found. There is a very large quantity of magnetite in the rock, not occurring in regular form, but rather filling the interstices between the other minerals. According to Rosenbusch this is a typical diabase.

No. 1082 (Plate X, Fig. 1., and Plate XI, Fig. 3.) is a diabase porphyrite, black in color, with light colored crystals varying from one sixteenth to three-sixteenths of an inch in length, scattered thickly through it. The specific gravity is 2.7. The fracture is distinctly conchoidal. In the aphanitic magma large twins of labradorite cut the rock in all directions. The following measurements of the feldspar crystals were made:

$20^\circ+23^\circ=43^\circ$ whole angle.
$35^\circ+30^\circ=65^\circ$ " "
$25^\circ+23^\circ=48^\circ$ " "

According to Pumpelly's method this would make the feldspar labradorite. The crystals are exceedingly regular in form, cutting each other in many directions. Inclusions in the crystals are frequent, presumably fragments of the magma. Colors of polarization gray, yellow and blue. Minute crystals of feldspar, all of about the same size, thickly dot the black magma. These are probably of the same kind as the larger crystals.

The next ingredient which attracts attention is the augite. This is not nearly as abundant as the feldspar and does not occur in as large crystals The form of the crystals is rarely regular, generally somewhat rounded. Inclusions of minute needles of apatite are frequent in the augite, also a greenish alteration product, otherwise it is unaltered.

No. 1083 (Plate XIII, Fig. 8.) is a weathered specimen of the same rock. The specific gravity is 2.66, being much lighter than the original rock. Here an excellent opportunity to study the effects of weathering is afforded. The augite has entirely disappeared, not a single crystal in the section possessing any of the augitic characteristics. A greenish product, much colored by the iron of the magma, probably represents the decomposed augite. The feldspar, while in many cases still retaining its crystalline form, is in every case altered, generally from the center. The figure shows one of the less altered crystals beginning to decay in the center. The alteration product is of a light green color, very irregular in form, but in a few cases the regular form of the primitive crystal is retained. The aphanitic magma of the unaltered rock has changed to a yellowish brown, with small crystals of magnetite dotting it all over.

No. 1082a (Plate XIII, Fig. 7.) is the next phase of the diabase. It is a somewhat porphyritic diabase of much lighter color than any of the preceeding, being almost reddish-brown, and showing somewhat the effects of weathering. The specific gravity is less also than any of the preceeding, being only 2.6. The fracture is somewhat conchoidal though not as much so as No. 1082. Under the microscope the effects of decomposition become very manifest. The large crystals of triclinic feldspar have altered to a mineral resembling orthoclase, but very much clouded. The smaller crystals of feldspar have likewise changed, though not as much as the larger ones. The chief peculiarity of the rock is the alteration of the augite into chlorite. These grains are, some of them, an eighth of an inch wide and so can be tested for their solubility in sulphuric acid. These grains are arranged in spherulitic masses, with radiating structure in polyhedra. There is a large amount of hematite and magnetite present in the section.

No. 1085 is banded sandstone, with alternate layers of brown and gray color. The grains are exceedingly minute, situated in a highly argillaceous magma. They are so small that they are very difficult to make out, but some of them are evidently triclinic feldspar from their form and angle of extinction.

No. 1088 (Plate XII, Fig 7.) is a very black rock, with none of its ingredients macroscopically visible. It has a shelly fracture and is quite brittle. Under the microscope it is seen to have a crystalline base of minute needles of plagioclase, in many cases twinned, with small grains of augite frequently surrounding them in sort of a pseudo-amydaloidal arrangement. Dotting the section are regular crystals, probably. magnetite. Here and there are found large crystals of plagioclase, with regular form and entirely unaltered. This rock is a typical diabase aphanite. It is situated on the southwest corner of the island, overlying a bed of conglomerate, which will be described later.

No. 1091 (Plate XII, Fig. 4.) is a specimen taken from the zone in contact with the conglomerate. It is dark in color, minutely crystalline and crossed in all directions by minute veins. Its specific gravity is 2.79. Small crystals of plagioclase are very abundant, also iron grains. The vein matter has aggregate polarization. Whatever augite is present it is entirely broken up, but still retaining its bright colors of polarization and angle of extinction. The amygdules here are small, generally greenish in color, without polarization or pleochroism. Alteration product much resembling olivine is present in large quantities. This rock is very similar to the one figured by Irving, on Plate IX, in his "Copper-bearing Rocks of Lake Superior."

The amygdaloids on the northwest corner island have not yet been carefully worked up by us. They are highly amygdaloidal containing large masses of calcite. Plagioclase, together with large the rock in all directions. The following measurements of the feldspar crystals were made:

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The amygdaloids on the northwest corner island have not yet been carefully worked up by us. They are highly amygdaloidal containing large masses of calcite. Plagioclase, together with large inch or two apart and which must have been subjected to the same agencies of metamorphism. One of these species presents all the characters of a typical granite with much quartz and orthoclase and few accessories. There is some pyrite, probably secondary. The orthoclase is much altered and gives aggregate polarization. The quartz grains are filled with numerous fracture lines and are rendered almost cloudy with microlitic inclusions, both apparently the result of intense heat and pressure. The other variety is unmistakably porphyry, with an almost irresolvable ground mass of quartz filled with large crystals of orthoclase, with now and then a large grain of quartz. These pebbles also appear to be very much altered from the action of heat. The orthoclase still can be determined by its aggregate polarization, crystalline outline and perpendicular extinction. In microscopic characters this rocks resembles very closely the porphyritic phase of the schist further down the river. A mile or so above the falls is a shining, fissile chloritic schist (No. 1027) which under the microscope proves to have a very uniform ground-mass of quartz and chlorite with a very little brown mica and numerous and regularly distributed minute unterminated crystals of an orthorhombic mineral with optical characters of staurolite. Much of the schist is of a highly metamorphic character, but preserves the usual strike and dip.

Nos. 1016, 1029, 1031, and 1036 are various phases of gneiss extending from a point one-half a mile east of the union of Mountain river with Dog river, in the line of strike, to intersect the coast severa miles northeast of the mouth of the latter. This series consists o several bands of varying width and texture interstratified and conformable with the schists. No. 1016 occurs along the shore near the Terraces forming high bluffs. It is a very fine-grained dark gneiss, with obvious bands of flesh-colored feldspar. Microscopically the mass of the rock is composed of much green muscovite mica, considerable epidote in zones (recognized by its bright yellow color,) relatively large amounts of oligoclase and decomposing feldspathic ingredient (orthoclase). There are innumerable needles of a transparent substance apparently derived from the mica. Some calcite is probably derived from the same source. Very little quartz is present.

No. 1036 is identical with No. 1016 and is from an adjacent exposure, but it is nearly schistose and the section exhibits a few vein of amorphous substance full of minute needles (sillimanite ?) like those above mentioned.

No. 1031 is the same gneiss where it intersects Mountain river. Here it is somewhat coarsely granular, containing more orthoclase and biotite mica. There is some (perhaps secondary) quartz in the confused portion. The transition to the schist is here very readily seen, there being no unconformity.

No. 1029 is a phase of No. 1031, just at contact with the schist and partakes of its characters. It has biotite in large quantities in conspicuous masses surrounded by irregularly disposed augite grains. The most of the remainder being plagioclase and orthoclase, with some quartz and an occasional large grain of calcite. The augite is very brilliantly polarized, but chiefly in grains or much broken crystals.

From the above it may be gathered that these gneissic rocks form really an integral part of the schists, being more highly metamorphosed than they. We incline to regard them as the axial part of the fold, the strata repeating to all appearances on either side, as indicated in our diagram. The relation of the strata is such as to permit us to consider the schist conglomerate a true basement conglomerate.

Passing beyond the gneiss the same series seems to be repeated in reverse order, though more careful examination is needed on this point.

No. 1037 resembles closely 1009 and is followed by No. 1038, which is identified with the conglomerate No. 1023. This is followed by schists. The contact of these schists with the granite is very suggestive. At a little distance from the contact, the schist (No. 1045) is a shining green chloritic mica schist, with light specks scattered through it. Under the microscope it is seen that the green mineral is arranged in wavy bands separating aggregates of quartz in a finely granular condition with large porphyritic brown grains, seemingly aggregates. Close examination shows however that the brown granular appearance masks calcite, with its cleavage and irridescence, and a comparison with the part more nearly adjacent to the granite shows the brown grains to have been feldspar from the latter.

No. 1046 is on the granite side of the contact and is an altered granite, having the quartz and feldspar imbedded porphyritically in a magma like that of the schist. The orthoclase is much altered by heat and the crystals are margined by calcite. The quartz is less fractured than in 1045, but on the whole the two are much alike. The original crystals of biotite (?) are broken up and greatly altered. The unaltered granite (No. 1042) is very coarsely granular and is perforated by many diabase dykes having the same general strike as in the schist. The granite continues to Little Bear river and thence to Dore' river, to the east of which a chloritic slate appears. The strike is S. 50° E. with a dip toward the southwest of about 45°, though the strata are very tortuous and embrace included masses. The contact with the granite is here as elsewhere evidence of the eruptive nature of the granite. Irving's map does not correctly represent the distribution of the granite in this bay. Gros Cap is the promontory west of Michipicoten harbor and is said to bear hematite veins. Bell says it is composed of slaty diorite, though the only rock seen by us was a tough silicious chlorite schist. At Michipicoten river the rocks are said to be dark hornblendic mica schist.

Leaving Gros Cap we crossed the entrance to Michipicoten harbor and encamped upon a narrow beach nearly directly south of the point. The rock here is strongly tortuous and confused. Much of the rock is porphyritic in a grayish-green base, while other portions are of dense close texture and uniformly micro-crystalline. In one place beneath the water the porphyritic rock could be seen to contain large rounded masses of a different color, often a foot or more in diameter. These were supposed to be similar to the conglomerate pebbles of the west side. As typical of much of the unporphyritic rock of this shore we select No. 1068, which appears to the eye like a moderately fine-grained diorite. The thin section shows it to have undergone great alteration. The greater part of the field is made up of elongated unterminated fibrous crystals, lying at all angles and frayed out at the ends. These are of a pale green color and scarcely pleochroic. The polarization colors are very brilliant, like those of tremolite. In cross section two sets of cleavage lines, with an apparent angle of 120-130° appear, while the longitudinal cleavage lines are frequently wavy. The twins are numerous and in the plane i-i, and the extinction angle $c : \mathfrak{c} =$ nearly exactly 15°. This combination of characters is hard to understand. The absence of pleochroism and brilliant polarization indicate a monoclinic augite, but the extinction angle, cleavage, and habit are like hornblende. This is, therefore, a decomposing hornblende like uralite in general appearance and like actinolite in characters. The iron has nearly disappeared from the whole rock, a few scales of hematite being found in the hornblende.

The remaining ingredients of the diorite, with the exception of the rather small amount of quartz, are more completely altered. The place of the plagioclase is taken by an opaque white amorphous substance and the interstices are filled with granular light material. A few crystals of decayed augite are seen, which have large quantities of iron in scales and grains. Here and there grains of calcite indicate where some of the decomposition products have gone. There are exposed a few interesting masses of ilmeníte, in which the hexagonal plates are matted obliquely, which show under the microscope the characteristic bronzy reflection.

No. 1064 is essentially similar. It is a very tough, homogeneous, greenish-grey rock. The actinolite is in the condition described above and the accessories are ilmenite, calcite, and apatite. It presents to the eye the appearance of a fine-grained diorite, altering to serpentine. Irregular bands of a lighter colored rock occur in this mass. Such a specimen is No. 1065, which is a confused mass of finely granular material in which quartz, calcite and chlorite can be identified. Strings or veins of calcite are abundant, and scattered through the magma are many dark grains, the centres of which are generally filled by a single crystal of secondary calcite.

No. 1066. This is the porphyritic phase before spoken of, which also contains the larger pebbles. Here and there in the section are large rounded grains of quartz, broken and intersected by the finely granular magma. The latter is not essentially different from the basis of 1065, but is crowded with rounded grains of oligoclase. Grains of secondary calcite and veins of the same, also pyrite and perhaps titanite are seen in the slide. It would appear that the magma is full of minute scales of chlorite. (Plate X, Fig. 2.)

The only explanation suggested for the curious condition of the rock here is that the metamorphism was excessive and resulted in a thorough suffusion of the original slate with intrusive matter as well as pasty portions of the adjacent sediments, reducing all to a somewhat homogeneous character. The conglomeritic phases of the slate being rendered pasty, the pebbles were at first unaffected and were intruded upon by the more fluid matter below. They were subjected to more violent flowage by reason of the obstinate pebbles during which the ingredients of the pebbles were partly set free and, although the magma was in part melted, the larger crystals remained dispersed in

PLATE XIV.

Fig. 1. *Myalina sp?*
Fig. 2. *Lingula umbonata*, Cox ; two valves in connection.
Fig. 3. *Straparollus ?*
Fig. 4. *Soleniscus medialis*, M. and W.
Fig. 5. *Soleniscus planus*, White?
Fig. 6. Probably the same species as Fig. 5.
Fig. 7. *Soleniscus fusiformis*, Hall.
Fig. 8. *Loxonema plebium*, sp. n.
Fig. 9. *Euomphalus subquadratus.*
Fig. 10. *Orthonema ?* sp.
Fig. 11. *Goniatites iowensis*, M. and W.
Fig. 12. *Dentalium* sp.
Fig. 13. *Nautilus forbesianus*, McChesney.
Fig. 14. *Conularia newberryi*, Meek?
Fig. 15. *Lingula scotica*, Davidson.
Fig. 16. Unidentified.
Fig. 17. *Pleurophorus immaturus*, sp. n.
Fig. 18. *Schizodus sub-circularis*, Her.
Fig. 19. *Schizodus*, cast of a very convex species.
Fig. 20. *Schizodus curtus*, M. and W.
Fig. 21. *Edmondia* (?) *reflexa*, Meek.
Fig. 22. *Gervillia ohioense*, Herrick.
Fig. 23. Tooth of fish ?
Fig. 24. Myalina (Modiolopsis ?)
Fig. 25. *Allorisma costata*, M. and W.
Fig. 26. *Pseudomonotus* sp ?
Fig. 27. *Placunopsis carbonaria*. M. and W.

VII.

THE CLINTON GROUP OF OHIO.—PART III.

BY A. F. FOERSTE.

BRYOZOA.

The Clinton Group of Ohio is remarkable for the fine preservation of a series of *Ptilodictyonidæ* of rather large size, and for the meagre representation of all other families of the bryozoa. In 1875, Hall and Whitfield described five species from the Soldiers' Home Quarries, in Ohio Paleontology, Vol. II. In 1878, U. P. James described two species, in The Paleontologist, No. I, in 1879, three more in No. III, of the same periodical; these specimens were collected in Clinton county, at an exposure three miles north of Wilmington, along Todd's Fork. In 1882, Hall described seven species, in Indiana Geol. Surv. 12th Ann. Report; the basis of these descriptions was some drawings and antiquated notes left by Mr. Van Cleve; the specimens were collected at Dayton, probably in the region of the Soldiers' Home Quarries. The drawings of Mr. Van Cleve were the work of an artist, rather than the careful copy by a naturalist of the specimens at hand. His bryozoa, however, are readily enough determined. These publications have given rise to quite a little synonomy considering the small number of species involved; our large collections, however, from the original localities will readily unravel any confusion that may exist.

In the following pages the system of classification used is that of Mr. E. O. Ulrich. This necessitates the change of many generic references. Unfortunate as this may be, when a name has become familiar and has been universally adopted, it is necessitated by very clear and universally recognized facts. The description of bryozoa has until recently consisted chiefly of the characterization of the external features of the specimen. Specimens of very different structure have often been associated together in incongruous genera, on the evidence of external features alone. In consequence also of that system of classification, generic values were ill understood, and types of genera could not prove a key to the situation. The new method has sought to furnish a scientific basis to this artificial classification, and an unflinching application of the universally recognized rules applying to the type species of genera, has made the avoidance of such changes simply impossible. In view of these facts it is rather amusing to notice the feeling among many of our American paleontologists that Mr. E. O. Ulrich is unsettling the foundations of the classification of bryozoa, when, in fact, he and the prominent European students of bryozoa, are merely doing all they can to give us a firm basis. Mr. Ulrich has assisted me so much in the investigation of bryozoa, by advice, criticisms, the presentation of specimens and the investigation of my own, that I can only express general indebtedness.

FENESTELLIDÆ, King.

Zoaria reticulated by the anastomosing of stems, or fenestrated by the coalescence of the short non-poriferous branches of adjacent stems, the dissepiments. Poriferous on one side only ; the cells sub-tubular, their mouths rounded.

GENUS PHYLLOPORINA, Ulrich.

Zoaria flabellate, perhaps infundibuliform when entire, consisting of anastomosing stems which form elongated, irregular meshes. Sections made transversely at some distance from the poriferous side show only one kind of cells. Sections passing just beneath the surface seem to pass through short interstitial cells, which are closed at the surface. Species of this genus have usually been referred to *Retepora, Lamarck*.

I. PHYLLOPORINA ANGULATA, *Hall.*

(*Plate* XV, *Fig.* 1; *Plate* XVII, *Fig.* 1.)

Retepora angulata ?, Hall and Whitfield (*R. Daytonensis* proposed), 1875; Ohio Pal. Vol. II, p. 111.

Retepora angulata, Hall, 1882; 12th Ann. Geol. Rep. Indiana, p. 269.

Frond found in flabellate fragments, originally perhaps infundibuliform, reticulated by the anastomosing of the dichotomously dividing stems, forming elongated fenestrules, which are of small size towards the base of the frond, increasing in size above; fenestrules from the same portion of the frond of about the same size. Poriferous side strongly convex, the non-poriferous side much less convex, and finely striated longitudinally. The cells are separated only by the cell-walls below, above they become constricted, opening upon the surface as small, rounded apertures which are more or less removed from each other, the intermediate portion seems often to be occupied by short interstitial cells not visible at the surface. The cells are arranged in four rows along the stems, the lateral rows opening directly upon the fenestrules. Cross-sections show that the two lower rows arise along the middle of the non-poriferous side and extend along the same to the lateral apertures, the two middle rows arise very near the origin of the lower rows, and open along the upper side of the stem. Partition walls extend longitudinally between the cells; in division, the middle wall usually divides dichotomously and terminates at the origin of the new branches, the two lateral walls form the central partition wall of the new branches; the lateral partition walls in the branches seem to arise from the middle wall by lateral division. During anastomosis, one or the other of the stems seems to prevail and to give direction to the cells of the new structure.

The ordinary variety of this species is of common occurrence, and is characterized by rather stout stems anastomosing at comparatively short intervals; another variety with equally stout stems has much more elongated fenestrules, 3 mm. or even more in length. The variety for which the name *R. Daytonensis* was suggested has very narrow branches, about .25 mm. broad, forming fenestrules 2.5 mm. long. This form is said to differ from the typical forms of *Ph. angulata* in "not possessing the angular ridges between the pores, and in having the borders of the pores elevated, forming the spur-like projections which that species does not show." In our specimens a nodose ridge along the middle of the stems is very evident. A similar ridge seems to extend along either side, thickening the inner side of the lateral rows of cell apertures. Since the alternate arrangement of cells is not regular, the lower cells are often brought beneath the upper ones, and then give them the appearance of having "a spur-like lip" on the lower side; and again, when these specimens are not free from the surrounding rock they may appear to have only two or three rows of cells, and this same arrangement may give the false impression that the cells "of the lateral ranges have the outer lip extended and elevated, bringing that side of the margin to a level with the inner margin." About 7 cells are found in a distance of 2 mm.

Locality and position. Soldiers' Home Quarries, Brown's Quarry, Fair Haven, Todd's Fork, Clinton Group.

GENUS HEMITRYPA, Phillips.

Zoaria infundibuliform, poriferous on the inside, with branches nearly straight and connected at regular intervals by non-poriferous dissepiments. Cells in two rows, separated by a thin median keel. The keel is supplied with elongated tubercles above; from the columns thus formed, slender lateral processes extend on either side to the centre of the space between the keels, where they are united into a delicate network, forming two series of openings between each pair of keels, the openings corresponding in number to the cells beneath.

II. HEMITRYPA ULRICHI, *sp. n.*

(*Plate* XV, *Fig.* 2; *Plate* XVII, *Fig.* 2.)

Frond infundibuliform below, broad and horizontally expanded above, the edges in large specimens decumbent. Diameter of the largest specimen seen, 40 mm; but fragments indicate that the specimens may attain a width of even 60 mm.

The poriferous side rarely shown and even then the pores are usually obscured by a peculiar network which is stretched above them. Branches with a median keel along the summit of which, situated at regular intervals, are a number of prominences from which slender processes extend horizontally to the centre of the space between the keels. The processes of adjacent branches unite along the middle of the space between the keels, forming a net, the circular openings of which usually alternate between the keels of adjacent branches, but are opposed when situated on opposite sides of the same keel. The mesh-work thus formed is very beautiful. The openings correspond in number and situation to the cells beneath. Microscopical sections show the cells to be angular below, becoming rounded and circular above, and opening laterally upon the sides of the branches. About three cells occupy the length of a fenestrule.

The non-poriferous side forms the upper or inner face of the frond, and is the face usually presented. The branches are of medium size, from 5 to 6, usually 5.5 in the width of 2 mm, remotely bifurcated, connected by dissepiments. Dissepiments strong, two-thirds as wide as the branches, in some cases wider, in others narrower, about 4 to 4.5 in the length of 2 mm. The branches appear smooth in perfect specimens, slightly striated longitudinally in worn specimens. The fenestrules are oblong in form, the corners rounded.

Named in honor of Mr. E. O. Ulrich, to whose kind assistance I am in many ways indebted.

The keels of *Hemitrypa dubia*, *Hall*, are connected by continuous transverse bars ; this species is therefore a member of the genus *Unitrypa*, *Hall*, and our Clinton species is undoubtedly the oldest species of *Hemitrypa* known.

Locality and position. Brown's Quarry, Clinton Group, common.

PTILODICTYONIDÆ, Zittel.

Zoaria consisting of compressed branching or simple leaf-like expansions, composed of two layers of cells, grown together, back to back, by the adhering of their epithecal laminæ. Interstitial cells, when present, never in the form of vesicular tissue.

GENUS CLATHROPORA, Hall.

Zoaria consisting of dichotomously dividing branches which anastomose at fairly regular intervals, forming a flabellate fenestrated frond. Interstitial cells entirely wanting.

III. CLATHROPORA FRONDOSA, *Hall.*

(*Plate* XV, *Fig.* 3; *Plate* XVII, *Fig.* 3.)

Clathropora frondosa, Hall, 1882, 11th Indiana Geol. Report.

Fronds flabellate, composed of branches which divide dichotomously at short intervals, forming short curves, which come in contact again, coalesce, and divide as before; by this means a fenestrated frond is produced, which would alternately consist of a series of short free branches or a series of rings along the growing edge, if the growth were regular. In that case the fenestrules would be also arranged in a concentric series of rows, the rows containing one more fenestrule after each reunion of the branches. As a matter of fact, bifurcation does not proceed in so regular a manner, but still enough regularity exists to place the fenestrules in something like lines or curves, which are often very striking. The fronds expand rapidly above, the sides forming broad, outward curves, the anterior edge being broadly rounded. The fenestrules are comparatively small, oval or even circular in shape. The cells are quadrangular, rhomboidal or hexagonal in form, never typically elongated. From 7 to 8 cells occupy a length of 2 mm. The number of cell-rows on the branches varies from 8 to 17. The fenestrules are also variable in size, an average size being 2 mm, varying to 3 mm. The fronds frequently become very large, attaining a length and breadth of 200 mm. The base of the fronds in the two specimens which alone preserved this portion was observed to be broadly rounded just beneath the first fenestrule, indicating that the frond was attached by the stipe to an articulating base; the latter has not been identified in our collections.

Locality and position. Soldiers' Home Quarries, Centreville, Clinton Group.

IV. CLATHROPORA CLINTONENSIS, *Hall and Whitfield.*

(*Plate* XV, *Fig.* 4; *Plate* XVII, *Fig.* 4.)

Clathropora Clintonensis, Hall and Whitfield, 1875; Ohio, Pal. Vol. II.

Fronds very similar to the last, the fenestrules varying from 2 to 5 mm. in length; typically they are of larger size than those of *C. frondosa*, and are more elongated and irregular in form, varying from oval to ovate, sub-rhomboidal, or even irregular in outline, the upper part of the fenestrules being frequently more or less acute. The comparative width of branches and enclosed fenestrules has no specific value whatever, the character of real importance being the form of the cells, which are elongated oval in form, the length equalling about twice the width. The cell apertures are arranged between quite prominent longitudinal ridges. From 6 to 7 cells occupy a length of 2 mm. The base of the only frond preserving this feature seems to pass without interruption into a stipe about 4 mm. broad and 18 mm. long, towards its origin the base becomes rapidly attenuated and may have articulated with some expanded, rooting structure. Until more specimens of this kind are discovered, this feature can have no value.

Locality and position. Soldiers' Home Quarries, very common at Fair Haven, Clinton Group.

GENUS PTILODICTYA, Lonsdale.

Zoaria wedge-shaped below, above expanding into an undivided leaf-like expansion. The cells are arranged in diagonal cross-rows or have a plumose arrangement, diverging in rows from central longitudinal series of cells, which usually are of smaller size. Interstitial cells wanting. A non-poriferous margin occurs in most species, this if present in the following species must be very narrow.

V. PTILODICTYA EXPANSA, *Hall and Whitfield.*

(*Plate* XV, *Fig.* 5; *Plate* XVII, *Fig.* 5.)

Phænopora (Ptilodictya) expansa, *pars*, Hall and Whitfield, 1875; Ohio, Pal. Vol. II. Plate V. fig. 1, is a specimen of *Phænopora platyphylla*, *James*, 1879.

Ptilodictya expansa, Hall, 1883; 12th Indiana Geol. Rep. The original description is here republished, but Plate 12, figs. 2 and 3 are correctly identified.

Frond arising from a wedge-shaped base, gradually enlarging, forming lanceolate expansions, or elongated oblong forms with parallel sides. Epithecal membrane marked by lunate lines of growth along the mesial series of cells, their convex sides directed forward; along the sides of broad specimens there are often longitudinal wrinkles, perhaps indicating that these specimens were derived from the narrower forms by lateral growth. Along the middle of the frond extend from 4 to 7 longitudinal series of cells, which are always conspicuously narrower than the lateral rows, in sections made just above the epithecal membranes. The central cells often show a tendency towards a secondary horizontal arrangement, the lateral cells however have also a well-defined secondary diagonal arrangement, diverging from the central rows of cells at an angle of about 15° above a line drawn horizontally across the surface of the frond. The smaller size of the mesial cells, and the diverging cells on either side give the frond a leaf-like or rather a plumose arrangement which is very characteristic.

Cells angular below, quadrangular or rhomboidal; rounded at their apertures, oval or almost circular; arranged between longitudinal raised lines. Fragments of variable size have been found, often 70 mm. long, without any evidence either of base or apex. Full grown specimens were probably 15 to 20 mm. in length. The broadest specimen with perfectly parallel sides seen was 16 mm. broad ; the broadest specimen of those of more irregular form measured 25 mm. from the mesial series of cells to the lateral edge, the entire width therefore was probably 50 mm. Mesial cells usually number 14 to 16 in a length of 4 mm; lateral cells, 10 to 14 in the same length. From 17 to 19 lateral cells occur in a width of 4 mm. The mesial cells are narrower than the lateral cells, but the degree of narrowness is variable.

There is not the least doubt of the identity of the first figure published with *Phænopora platyphylla, James*, a form related to *Ph. constellata, Hall*, with which species, indeed, the authors compared our Ohio specimens. But the identification made by Hall, among the figures prepared by Van Cleve, evidently shows that the authors had an elongated species in mind which they considered typical.

Again most of the distinct features mentioned in the original description are those of *Ptilodictya expansa*. These are : " fronds forming . . . elongate stipes, . . . the lateral edges are . . generally parallel, . . . thin longitudinal partitions . . . slightly raised above the upper and lower walls of the cells, . . . cells . . . in horizontal, or nearly horizontal, rows, diverging from the *central partition* at an angle of about fifteen degrees above a horizontal." The reference to " maculæ " is of course a description of features belonging to the specimen of *Phænopora platyphylla* figured. There is some doubt as to the meaning of the words "" central partition" which I have italicised. If these refer to the narrow mesial cell rows, the description is intelligible and pertinent ; if not, it has no tangible meaning for either species. We believe that in this case, where we have two generic references, a description including characteristics of two species, and figures of two species, it is most advisable to make the original description the material from which to unravel the form which is to be considered authentic.

Locality and position. Forms with parallel sides are found frequently at Todd's Fork, Clinton county, and rarely at the Soldiers' Home Quarries. Broader forms with less regular sides are common at the Soldiers' Home Quarries. Clinton Group.

GENUS PHÆNOPORA, Hall.

Zoaria forming simple or branching fronds without a distinct nonporiferous edge; the pores of the edge seem to be of the same rank with the interstitial cells. Cells arranged in longitudinal series, separated at their ends typically by two interstitial cells, although their number may be so increased in different parts of the same frond as to even completely surround the cells. A transverse septum at the base of the cells is also characteristic. The bases of the zoaria are attenuated and rounded, or somewhat pointed, showing that articulation had formerly existed with some fixed base.

VI. PHÆNOPORA PLATYPHYLLA, *James.*

(*Plate* XVI, *Fig.* 1 ; *Plate* XVII, *Fig* 6.)

Phænopora (Ptilodictya) expansa, *pars*, Hall and Whitfield, including Plate V, fig. 1.

Ptilodictya platyphylla, James, 1879, Paleontologist. No. 3.

Ptilodictya bipunctata (Van Cleve) Hall, 1883. 12th Indiana Geol. Report.

Frond beginning with a small, narrow stipe, which at its origin is obtusely pointed, or almost rounded, indicating articulation with some attached base, rapidly widening above into a broad flabellate expansion, the contour in general being rounded, but flexuous in certain places where growth has been irregular; never branched. The surface covered by conspicuous, rounded tubercles, having a tendency to arrange themselves in rows, about six tubercles appearing in a length of 15 mm; sometimes the tubercles have a tendency to be somewhat pointed. The surface is occupied by the cell mouths, which are very small, circular, or slightly oval, arranged in longitudinal series, about eight in the length of 2 mm. Typically two interstitial cells are found at the extremities of the cells; in some specimens, however, additional interstitial cells appear along the sides of the cell, or even at the extremities, so that the cells are sometimes completely surrounded by interstitial cells. The cell rows are separated by raised ridges, which appear like a narrow line running between the rows and closely pressed by the cells and interstitial cells on either side; or they become quite broad and poorly defined, bearing on their surface all the laterally situated interstitial cells, the mouths of which are apt to be of an elongated rather than circular shape; whenever the interstitial cells become very numerous these separating ridges are apt to disappear entirely in a disordered mass of cells and interstitial cells. All these changes may appear in one and the same species. At the summit of the tubercles one or more cells are apt to be suppressed; their places are then taken by interstitial cells. The edges of the frond are acute; no non-poriferous margin has been observed, but considering the nature of the growth of the species, this is rather to be expected. Specimens are usually found divided in the middle, the epithecal laminæ being exposed, and the celluliferous faces being adherent to the rock in which the specimens were imbedded. The epithecal membrane is smooth, or wrinkled transversely in curves, which to some degree mark various stages of growth, and conform therefore with the general outline of the flabellate frond. Through the epithecal membrane longitudinal lines may be seen, which are the laminæ that separate the cell rows: between these are diagonal lines dividing the surface into small subimbricating rhombs; sometimes short transverse lines intersect the diagonal lines of the rhomb. From the epithecal laminæ the cells diverge to the opposite faces of the frond, making an angle of 65° or more with the epithecal laminæ.

Fronds vary in size: one of the largest specimens seen being 100 mm. broad and 130 mm. long. Eight cells are found in the length of 2 mm; eight or nine rows occupy the same distance measured transversely. The thickness varies from a thin expansion to a frond 2 mm. thick, rarely attaining a thickness of even 5 mm.

The figure accompanying the original description of *Ptilodictya expansa, Hall and Whitfield*, belongs to this species and the description of that species shows that specimens of this species were by mistake used in the determination of its characters. This species is evidently closely related to *Ph. constellata*, *Hall*, from the Clinton Group of Canada. A specimen from Hamilton, Ontario, before me, may be distinguished by the fact that the monticules appear only as slightly elevated patches, and the thickness of the frond is reduced to very small dimensions, perhaps .7 mm, and the frond seems to have been of small size. Specimens collected by Prof. N. S. Shaler, however, from Anticosti, Canada, show all the features of our Ohio specimens.

Locality and position. Soldiers' Home Quarries, Allen's Quarry, Fair Haven, Todd's Fork, Clinton Group.

VII. PHÆNOPORA MAGNA, *Hall and Whitfield.*

(*Plate* XV, *Fig.* 6; *Plate* XVI, *Fig.* 2; *Plate* XVII, *Fig.* 7.)

Stictopora magna, Hall and Whitfield, 1875, Ohio, Pal. Vol. II.
Stictopora compressa, (Van Cleve) Hall, 1883, 12th Indiana Geol. Report.

Frond beginning with a narrow stipe which is rounded at its origin, indicating that its base was articulating, gradually widening, until it attains a width of about 6 mm, then branching dichotomously. The dichotomous character of the branching is frequently obscured by the unequal development of the branches and by the unequal intervals between the places at which branching takes place. When the specimens exist only as fragments, pieces of fair size may sometimes be found which seem to be portions of lengthened, undivided fronds, and it is very probable that species of this genus have been described as unbranched, simply because the material in hand was fragmentary. The general appearance of the frond varies, therefore, exceedingly, from a long, scantily branched specimen, to one whose numerous branches look like narrow ribbons woven together. The angles at which the specimens branch vary exceedingly, from small angles of only 10°, in which the bending of the branches for even a slight distance is sufficient to make them overlap each other, or assume a parallel direction, to angles of 80° or even 90°. The surface is covered by conspicuous tubercles, usually low, broad, and rounded, but sometimes pointed and well defined, with a less regular arrangement than in the former species, or even scattered; about 5 tubercles usually occupy a length of 9 mm, although this is subject to great variation.

The cell mouths are small, circular, or slightly oval, arranged in longitudinal series, about eight in a length of 2 mm; ten or eleven of these series are found in a width of 2 mm. The longitudinal series are well defined by thin, slender, raised lamellæ, without the complex structure mentioned in the former species. The lamellæ separating the cells from the interstitial cells appear at the surface like fine threads, connecting the longitudinal lamellæ, and they cross each other at equal distances between the same, thus enclosing two interstitial cells at the ends of the cells. In the tubercles they become more numerous and either surround the cells or entirely supplant the same. The branches are quite thin and flat; the edges are thin and sharp, and are occupied by minute pores or cells, corresponding in size to the interstitial cells and forming only a narrow margin. Interstitial pores are apt to be numerous in the cell rows along the edges of the branches. Specimens usually divided at the centre, showing the epithecal laminæ; these are wrinkled transversely, the wrinkles being lunate in the middle of the frond, and deflected backwards on either side to the margin. The exterior surface is rarely seen.

Fronds vary in size, a well grown specimen being 110 mm. long and 80 mm. broad; the branches vary between 5 and 8 mm. in width, and a form found at Fauver's Quarry occasionally attains a width of 10 mm Their thickness varies between 1.5 and 2 mm.

Locality and position. Soldiers' Home, Brown's Quarry (a narrow variety), and Fauver's Quarry, Clinton Group.

VIII. PHÆNOPORA MULTIFIDA, (*Van Cleve*) *Hall.*

(*Plate* XVI, *Fig.* 3.)

Ptilodictya (sp ?) James, 1878, Paleontologist, No. 1. (Name, *P. Welshi* suggested.

Stictopora multifida, (Van Cleve) Hall, 1883, 12th Indiana Geol. Report.

Frond beginning with a narrow stipe, gradually widening until a breadth of 4 or 5 mm. is attained, then branching dichotomously at small angles, the branches remaining parallel. The branches may lie closely together and almost touch one another. They are rarely more than their width apart. The usual form is that of a series of parallel branches forming a sub-triangular frond by means of dichotomous division, the branches at their tip being a fifth or a sixth of their breadth apart, and at the base touching one another, sometimes forming a continuous frond near the stipe, and at other times being open like the branches above. All specimens seen were divided at the epithecal membrane, which is wrinkled transversely by lines of growth, lunate in the middle, the ends deflected backwards along the sides, the rounded ends of the branches are preserved on some of the specimens. In specimens whose branches have become contiguous and have grown together at the base of the frond, the wrinkles or lines of growth still indicate readily the position of the branches.

Branches thin and flat, the exterior surface not seen, but the cross-sections made gave no evidence of tubercles, and therefore the surface is believed to be flat. Cells oval, arranged in longitudinal series, 8 cells in a distance of two mm, and 10 or 11 series occupying the same distance in breadth. The series of cells are separated by thin, straight lamellæ, which are not intruded upon by either cells or interstitial cells. Interstitial cells, two, between the ends of the cells, becoming more numerous in one or two of the marginal series; the margin is thickly supplied with them, making it poriferous; poriferous margin narrow.

Frond about 75 mm. long and 70 mm. broad. Branches from 2.5 to 4 mm. broad. Cells, 8 in a distance of 2 mm, measured longitudinally, 10 or 11 in the same distance measured transversely.

It will be noted that this species assumes a sort of intermediate position between the last and the following. In fact the difference in the width of the cells and the different manner of branching, both variable factors, alone distinguish them one from the other.

Locality and position. Soldiers' Home Quarries, collection of Mr. Geo. Caswell. Also, Brown's Quarry, a form with more distant branches. Clinton Group.

IX. PHÆNOPORA FIMBRIATA, *James.*

(*Plate* XV, *Fig.* 7.)

Ptilodictya fimbriata, James, 1878, Paleontologist, No. 1.
Stictopora Van Clevii, Hall, 1883, 12th Indiana Geo. Report.

Frond arising from a small narrow stipe, attenuated towards the base, expanding gradually above until a width equal to the branches is attained; then branching dichotomously at variable intervals in different or even in the same specimens; the branches usually flexuose, forming characteristic meshes upon the surface of the rock. Surface unknown, but from numerous sections believed to be destitute of tubercles. The branches are quite thin and flat, with sharp edges.

Cells arranged in longitudinal series, about eight in a length of 2 mm. and ten or eleven in the same distance in breadth. Two interstitial cells are found between the ends of the cells, becoming more numerous in the lateral series of cells, and entirely pervading the tissues of the edges of the branches, which as a consequence appear striated in worn specimens. The branches are usually narrower than those of the last species, eight to twelve series of cells occupying the branches in this species, whereas in that species twelve to fifteen series are usually found.

The largest frond so far observed, evidently not an entire specimen, was 65 mm. long, and 50 mm. broad. The branches vary from 2.3 to 3.2 mm, and sometimes attain a thickness of 1.2 mm.

Associated with these species are long, slender fronds, undivided, with the characteristic cells and interstitial cells of the group, the latter pervading the edges of the frond. One specimen is 55 mm. long and 5 mm. broad. They are probably the broken off stipes of some of the species last described. That the species all form a closely allied group may readily be seen.

Locality and position. Soldiers' Home Quarries, Todd's Fork, Fauver's Quarry, Allen's Quarry, Fair Haven, Clinton Group.

GENUS PACHYDICTYA, Ulrich.

Zoaria composed of thick, often irregularly branching fronds, with distinct, smooth, non-poriferous margins. The cell walls are distinct and regular, neatly enclosing the oval cells; at their ends they are usually approximate, nearly but not quite touching, the cells being arranged in longitudinal series; laterally, however, they are always separated from each other by two quite thick lamellæ which are continuous between the cell rows, following up the contour of the cells, but separated along the middle by a curved or quite straight line, which sometimes is indistinct. Species of this genus are usually referred to *Stictopora*, but in that genus the cells are separated by a series of small spiniform tubuli.

X. PACHYDICTYA EMACIATA, *sp. n.*

(*Plate* XV, *Fig.* 8; *Plate* XVII, *Fig.* 8.)

Frond not known in its entire state, only one specimen (and that a fragment) seen. The specimen is 26 mm. long and 22 mm. broad, being divided dichotomously into branches at angles of about 45°.

The branches are 3 mm. wide and scarcely ⅔ mm. thick. The cells are arranged in longitudinal series, forming at the same time more or less accurate oblique cross-rows. Cells oval, narrow in the middle rows, broader in the lateral rows, about 6 occupying a length of 2 mm, and 11 series the same distance in breadth; 10 to 13 series are found on the various branches. The longitudinal series are separated by raised longitudinal lines, inclined to be flexuose on account of the diagonal lines, in which the cells dispose themselves ; occasionally these ridges seem to bear 2 or 3 fine striæ. The margins of the branches show faint traces of striæ.

From the succeeding species it may be distinguished by the thinness of its branches, the wider non-poriferous margin, and the greater number of its cells in transverse measurement. Name signifies *thinned* or *grown thin*.

Locality and position. Soldiers' Home Quarry, Clinton Group.

XI. PACHYDICTYA BIFURCATA, (*Van Cleve*) *Hall.*

(*Plate* XV, *Fig.* 9; *Plate* XVII, *Fig.* 9.)

Stictopora bifurcata, (Van Cleve) Hall, 1883, 12th Indiana, Geol. Report.

Frond arising from a narrow stipe, attaining the size of the branches above, then branching rapidly below, less frequently above, at angles between 30° and 50°. The branches are convex and decidedly thickened, their thickness exceeding half their width. The surface even and smooth, at least not tuberculate, channeled lengthwise, the cells placed in the channels, five and a half or six found in a length of 2 mm, and six or seven in the same distance in breadth. The cells are oval, slightly separated at the ends by the dividing lamellæ; the longitudinal series are usually separated to quite a marked degree by thick lamellæ, which are marked longitudinally along the summit by faint undulating striæ. The edges of the branches are non-poriferous and smooth, or very indistinctly striate, obtuse, but with a narrow salient margin indicating the position of the epithecal lamina.

The largest specimen found was 160 mm. long and 85 mm. wide; the branches are somewhat flexuose, about 4 to 5 mm. broad, and from 2 to 3 mm. thick. This form may be compared with *P. acuta, Hall*, from the Trenton Group of New York.

Locality and position. Soldiers' Home Quarries, Fair Haven. Clinton Group.

XII. PACHYDICTYA BIFURCATA, VAR. INSTABILIS, *var. n.*

(*Plate* XV, *Fig.* 10.)

Frond known only by fragments 30 to 40 mm. long and broad, branching dichotomously at wide and variable angles. The branches from 3 to 5 mm. wide and from 1 to almost 2 mm, thick; the surface uneven, more or less tuberculated, the tubercles low but generally distinct, without evident arrangement, about 4 tubercles in a distance of 80 mm, measured longitudinally.

The cells are oval, from 6 to 7 occupying a length of 2 mm, usually nearer the latter number, and from 8 to 9.6 rows occupying the same distance in breadth. The non-poriferous edges narrow in the specimens examined.

Whether this form is distinct from the last one, it is difficult to tell. Where there are so many species of a genus, occurring in such abundance, their form is usually very variable, and the distinctions between species are not always well defined. Judging from the specimen at hand, it is difficult and perhaps impossible to distinguish between the forms specifically, and intermediate forms seem to occur.

Locality and position. Brown's Quarry, Clinton Group. The species occurs here in all its forms apparently. The extreme, nodulated or tuberculated forms, which are separated here as a variety predominate.

XIII. PACHYDICTYA TURGIDA, *sp n.*.

(*Plate* XV, *Fig.* 11; *Plate* XVII, *Fig.* 11.)

Fronds variable, branching dichotomously at angles from 30° to 50°; branches more or less thickened, the edges inclined to be obtuse with a salient line along the epithecal lamina, the margin non-poriferous. Cells oval, 12 in a distance of 5 mm, measured along the longitudinal series, 16 series in the same distance in breadth. Two or three faint flexuose lines are found on the ridges separating the series.

The surface is tuberculate; the tubercles are of variable distinctness, and are arranged in something like order, from 4 to 5 in a distance of 10 mm. The tissue in the tubercles becomes very thick, the arrangement of the cells is somewhat disturbed and their number reduced.

The largest fragment at hand is 55 mm. long and 35 mm. broad. The branches vary from 6 to 9 mm. in width, and from 1.8 mm. to 3.5 mm. in thickness.

Name signifies *thick, swollen,* referring to the thickened fronds. This form may be compared with *P. fenestelliformis, Hall,* as identified by Mr. E. O. Ulrich, from the Cincinnati Group of Illinois.

Locality and position. Soldiers' Home Quarries, Fair Haven, Clinton Group.

XIV. PACHYDICTYA OBESA, *sp n.*.

(*Plate* XV, *Fig.* 12.)

The structure of this species is very similar to the last, but the fronds are broader, apparently undivided, and usually thicker, forming coarse, often undulating or folded fronds. Tubercles much more distinct, with a more decided tendency for arranging themselves in series, 4 to 5 in a distance of 10 mm. Tangential sections show that the number of cells is decreased in the tubercles by the turgescence of the surrounding laminæ, or by the entire suppression of cells. One of the largest fronds at hand is a fragment 65 mm. long, 37 mm. wide and 5 mm. thick. Some specimens are not so thick, but still thick enough to attract attention to this feature. It may be compared with *P. gigantea, Ulrich,* from the Cincinnati Group of Illinois.

Name signifies, *very thick and swollen, fat.*

Locality and position. Soldiers' Home Quarry, Clinton Group.

CYSTODICTYONIDÆ, Ulrich.

Zoaria consisting of two or more layers, grown together along their epithecal membranes. Cell apertures with a crescentic lip. Interstitial spaces occupied by vesicular tissue, which in the matured stage is almost obliterated by a secondary deposit of sclerenchyma, apparently perforated by minute, vertical, communicating canals. Margins o zoaria non-poriferous. (Ulrich, Am. Pal. Bry. April, 1884.)

GENUS RHINOPORA, Hall.

Zoaria consisting of two laminated expansions, grown togethe along their epithecal membranes; the margins are non-porifero The cell apertures are strongly raised above the surface in little papi lae or pustules. The aperture itself is quite small and usually appea more or less irregular in form, suggesting the crescentic lip so cha acteristic of the *Cystodictyonidae* and *Fistuliporidae*. The interstitial ti sue, if any, seems to have been obliterated by the secondary deposit o sclerenchyma.

XV. RHINOPORA VERRUCOSA, *Hall.*

(*Plate* XV, *Fig.* 13: *Plate* XVII, *Fig.* 12.)

Rhinopora frondosa, Hall and Whitfield, 1875, Ohio, Pal. Vol. II.
Escharina (?) distorta, James, 1873. The Paleontologist, No. 3.
Rhinopora venosa, Spencer, 1884, Niagara Fossils, St. Louis Acad. Science Vol. IV, No. 4.
Cf. Rhinopora curvata, Ringueberg, Bull. Buffalo. Soc. Nat. Sc., Vol. V No. 1.

Fronds forming thin expansions, the defining margins being shar and distinctly non-poriferous. Specimens usually occur in the form o fragments, smaller pieces of which appear flattish, and some pieces o even fair size may be found with only a moderate amount of curva ture. However, when broken from the solid rock, parting along th epithecal membranes, expansions may be followed for 30 mm. or mor through the rock, contorted and curved in almost every possible man ner. Proper branching does not take place, but the outlines of th fronds are often quite irregular. The character of the base of th frond is unknown. The cells are arranged in diagonally intersectin rows which may be quite straight for a moderate distance, but usuall are somewhat curved. This arrangement may be perfectly maintaine over quite a large portion of the surface, but frequently is perfect onl in small patches, the rows of which do not perfectly join each other on account of the introduction of new rows, the sudden curvature o a series of rows, or on account of the disturbing influences of the structure next to be described. Between the cell rows at variable distances over the frond are distributed a number of raised lines which are more or less connected with each other and have the appearance of a branching structure trailing over the surface of the frond. These may become quite conspicuous and form a marked feature of the frond, but they do not seem to have any very intimate connection with the rest of the frond. This they very frequently show by entirely weathering away from the surface of the frond. The place they occupied is then marked by a groove which becomes quite conspicuous in the specimens which were characterized by large raised lines. These raised lines extend along the grooves between the cell rows usually including and resting upon the inner half of the cells between which they extend. Usually they leave the arrangement of the cells unaffected, but the arrangement of the rows may be more or less disturbed in crossing these lines. At the junction of the raised lines, especially where several lines meet, the cells are apt to be more separated at this point than elsewhere on the frond; the cells then frequently become of somewhat larger size, are more prominent, and form slightly elevated clusters of moderate size, over the surface of the frond, which sometimes occur at quite regular intervals and form conspicuous features of the frond. When the raised lines in such specimens were quite narrow and then weathered away, these low elevations are still more conspicuous. The center of the elevations is frequently marked by an irregular, non-celluliferous portion where the lines meet; these spaces then may suggest maculæ. The prominent surrounding cells of the elevated parts are frequently crowded back upon each other for a short distance by the dividing ridges and then also are more inclined to form conspicuous elevations. The apertures of the cells are produced in the form of round papillæ above the surface of the frond. The mouth is situated at the very summit of the papillæ, but may appear more or less lateral by the unequal wearing away of the cells. Near the base on one side of the cell may be found a small depression, the precise nature of which is unknown. It may have had some connection with the interior of the frond, but such connection has not been established. No interstitial tissue has been satisfactorily determined. The cells vary from 50 to 60 in the distance of 25 mm. In *R. tubulosa*, *Hall*, they are said to be more crowded, numbering from 80 to 85 in the same distance.

This species is seen to be quite variable, but there is no difficulty at all in tracing the connection of the different forms in any collection which contains a large number of specimens in a good state of preservation. As might be expected, its distribution is also quite wide, extending from New York to Ontario and Ohio, and being found both in the Niagara shales and in the Clinton Group.

Locality and position. Brown's Quarry, Soldiers' Home Quarries, Centreville, Fair Haven, Todd's Fork, Clinton Group.

FISTULIPORIDÆ, Ulrich.

This family is closely allied to the *Cystodictyonidæ*, from which it differs in the absence of non-poriferous margins and in having no secondary deposit obscuring the presence of the interstitial cells, or at least, when present, being quite superficial.

Genus LICHENALIA, Hall.

Zoaria composed of a single layer of cells, the epithecal side being concentrically wrinkled, the wrinkles being supplemented by secondary finer concentric striæ; when the epithecal membrane is translucent, the bases of the cells may be frequently seen in the form of short, radiating striæ. Cells with a crescentic lip at the aperture which is continued into the tube of the cell in the form of two longitudinal inflections of the cell walls. Interstitial cells always present, separating the cells.

XVI. Lichenalia concentrica, *Hall.*

(*Plate* XVII, *Fig.* 10.)

No specimens of this species have been found in my own collections, but it is represented by several specimens in the cabinet of Dr. L. B. Welch. The following short description of this species is therefore added.

Zoaria forming circular flattened expansions, often 130 mm. in diameter, celluliferous on one side only, the arrangement of the cells being disturbed in some varieties by the presence of maculæ. Cells separated by angular interstitial cells. Non-celluliferous face wrinkled concentrically.

Locality and position. Clinton County, Clinton Group, collection of Dr. L. B. Welch.

CERAMOPORIDÆ, Ulrich.

Zoaria usually incrusting, sometimes ramose with hollow branches, or flabellate. Cell apertures triangular or ovate, with a prominent and arched lip usually on one side. (Ulrich, Am. Pal. Bry.)

GENUS CERAMOPORA, Hall.

Usually incrusting. Cells angular, with the lip strongly arched, the aperture oblique; cells radiating from one or more centers. (Ulrich, Am. Pal. Bry.)

XVII. CERAMOPORA EXPANSA, *James.*

(*Plate* XVII, *Fig.* 13.)

Alveolites expansa, James, 1879, Paleontologist, No. 3.

"Corallum, a flat or undulating expansion, irregular in outline, 6 inches or more in diameter, varying in thickness from less than one to over two lines. Corallites very oblique and more or less sinuous in their direction from the base or central axis to the surface. Calices very narrow, slightly curved, elongated slits, showing, generally, when a little weathered, a tooth-like projection in the middle of the upper lip, and arranged sometimes in series of short curved rows in a more or less alternating manner. About 4 calices in the space of a line. Walls of corallites thick.

"Although the specimen from which this description is made was found spread over the surface of a rock—from which it readily scaled off—it is not certain that it was *encrusting*, as there is an appearance of something like a central axis from which the corallites grew in different directions to opposite surfaces, in a very oblique manner; portions of the side next the rock show calices similar to the other longitudinal series, about eight in a length of 2 mm; ten or eleven of these series are found in a width of 2 mm. The longitudinal series are well defined by thin, slender, raised lamellæ, without the complex structure mentioned in the former species. The lamellæ separating the cells from the interstitial cells appear at the surface like fine threads, connecting the longitudinal lamellæ, and they cross each other at equal distances between the same, thus enclosing two interstitial cells at the ends of the cells. In the tubercles they become more numerous and either surround the cells or entirely supplant the same. The branches are quite thin and flat; the edges are thin and sharp, and are occupied by minute pores or cells, corresponding in size to the interstitial cells and forming only a narrow margin. Interstitial pores are apt to be numerous in the cell rows along the edges of the branches. Specimens usually divided at the centre, showing the epithecal laminæ; these are wrinkled transversely, the wrinkles being lunate in the middle of the frond, and deflected backwards on either side to the margin. The exterior surface is rarely seen.

Fronds vary in size, a well grown specimen being 110 mm. long and 80 mm. broad; the branches vary between 5 and 8 mm. in width, and a form found at Fauver's Quarry occasionally attains a width of 10 mm Their thickness varies between 1.5 and 2 mm.

Locality and position. Soldiers' Home, Brown's Quarry (a narrow variety), and Fauver's Quarry, Clinton Group.

VIII. Phænopora multifida, (*Van Cleve*) *Hall.*

(*Plate* XVI, *Fig.* 3.)

Ptilodictya (sp ?) James, 1878, Paleontologist, No. 1. (Name, *P. Welshi* suggested.

Stictopora multifida, (Van Cleve) Hall, 1883, 12th Indiana Geol. Report.

Frond beginning with a narrow stipe, gradually widening until a breadth of 4 or 5 mm. is attained, then branching dichotomously at small angles, the branches remaining parallel. The branches may lie closely together and almost touch one another. They are rarely more than their width apart. The usual form is that of a series of parallel branches forming a sub-triangular frond by means of dichotomous division, the branches at their tip being a fifth or a sixth of their breadth apart, and at the base touching one another, sometimes forming a continuous frond near the stipe, and at other times being open like the branches above. All specimens seen were divided at the epithecal membrane, which is wrinkled transversely by lines of growth, lunate in the middle, the ends deflected backwards along the sides, the rounded ends of the branches are preserved on some of the specimens. In specimens whose branches have become contiguous and have grown together at the base of the frond, the wrinkles or lines of growth still indicate readily the position of the branches.

Branches thin and flat, the exterior surface not seen, but the cross-sections made gave no evidence of tubercles, and therefore the surface is believed to be flat. Cells oval, arranged in longitudinal series, 8 cells in a distance of two mm, and 10 or 11 series occupying the same distance in breadth. The series of cells are separated by thin, straight lamellæ, which are not intruded upon by either cells or interstitial cells. Interstitial cells, two, between the ends of the cells, becoming more numerous in one or two of the marginal series; the margin is thickly supplied with them, making it poriferous; poriferous margin narrow.

Frond about 75 mm. long and 70 mm. broad. Branches from 2.5 to 4 mm. broad. Cells, 8 in a distance of 2 mm, measured longitudinally, 10 or 11 in the same distance measured transversely.

It will be noted that this species assumes a sort of intermediate position between the last and the following. In fact the difference in the width of the cells and the different manner of branching, both variable factors, alone distinguish them one from the other.

Locality and position. Soldiers' Home Quarries, collection of Mr. Geo. Caswell. Also, Brown's Quarry, a form with more distant branches. Clinton Group.

IX. PHÆNOPORA FIMBRIATA, *James.*

(*Plate* XV, *Fig.* 7.)

Ptilodictya fimbriata, James, 1878, Paleontologist, No. 1.
Stictopora Van Clevii, Hall, 1883, 12th Indiana Geo. Report.

Frond arising from a small narrow stipe, attenuated towards the base, expanding gradually above until a width equal to the branches is attained; then branching dichotomously at variable intervals in different or even in the same specimens; the branches usually flexuose, forming characteristic meshes upon the surface of the rock. Surface unknown, but from numerous sections believed to be destitute of tubercles. The branches are quite thin and flat, with sharp edges.

Cells arranged in longitudinal series, about eight in a length of 2 mm. and ten or eleven in the same distance in breadth. Two interstitial cells are found between the ends of the cells, becoming more numerous in the lateral series of cells, and entirely pervading the tissues of the edges of the branches, which as a consequence appear striated in worn specimens. The branches are usually narrower than those of the last species, eight to twelve series of cells occupying the branches in this species, whereas in that species twelve to fifteen series are usually found.

The largest frond so far observed, evidently not an entire specimen, was 65 mm. long, and 50 mm. broad. The branches vary from 2.3 to 3.2 mm, and sometimes attain a thickness of 1.2 mm.

Associated with these species are long, slender fronds, undivided, with the characteristic cells and interstitial cells of the group, the latter pervading the edges of the frond. One specimen is 55 mm. long and 5 mm. broad. They are probably the broken off stipes of some of the species last described. That the species all form a closely allied group may readily be seen.

Locality and position. Soldiers' Home Quarries, Todd's Fork, Fauver's Quarry, Allen's Quarry, Fair Haven, Clinton Group.

GENUS PACHYDICTYA, Ulrich.

Zoaria composed of thick, often irregularly branching fronds, with distinct, smooth, non-poriferous margins. The cell walls are distinct and regular, neatly enclosing the oval cells; at their ends they are usually approximate, nearly but not quite touching, the cells being arranged in longitudinal series; laterally, however, they are always separated from each other by two quite thick lamellæ which are continuous between the cell rows, following up the contour of the cells, but separated along the middle by a curved or quite straight line, which sometimes is indistinct. Species of this genus are usually referred to *Stictopora*, but in that genus the cells are separated by a series of small spiniform tubuli.

X. PACHYDICTYA EMACIATA, *sp. n.*

(*Plate* XV, *Fig.* 8; *Plate* XVII, *Fig.* 8.)

Frond not known in its entire state, only one specimen (and that a fragment) seen. The specimen is 26 mm. long and 22 mm. broad, being divided dichotomously into branches at angles of about 45°.

The branches are 3 mm. wide and scarcely ⅔ mm. thick. The cells are arranged in longitudinal series, forming at the same time more or less accurate oblique cross-rows. Cells oval, narrow in the middle rows, broader in the lateral rows, about 6 occupying a length of 2 mm, and 11 series the same distance in breadth; 10 to 13 series are found on the various branches. The longitudinal series are separated by raised longitudinal lines, inclined to be flexuose on account of the diagonal lines, in which the cells dispose themselves; occasionally these ridges seem to bear 2 or 3 fine striæ. The margins of the branches show faint traces of striæ.

From the succeeding species it may be distinguished by the thinness of its branches, the wider non-poriferous margin, and the greater number of its cells in transverse measurement. Name signifies *thinned* or *grown thin*.

Locality and position. Soldiers' Home Quarry, Clinton Group.

XI. PACHYDICTYA BIFURCATA, (*Van Cleve*) *Hall.*

(*Plate* XV, *Fig.* 9; *Plate* XVII, *Fig.* 9.)

Stictopora bifurcata, (Van Cleve) Hall, 1883, 12th Indiana, Geol. Report.

Frond arising from a narrow stipe, attaining the size of the branches above, then branching rapidly below, less frequently above, at angles between 30° and 50°. The branches are convex and decidedly thickened, their thickness exceeding half their width. The surface even and smooth, at least not tuberculate, channeled lengthwise, the cells placed in the channels, five and a half or six found in a length of 2 mm, and six or seven in the same distance in breadth. The cells are oval, slightly separated at the ends by the dividing lamellæ; the longitudinal series are usually separated to quite a marked degree by thick lamellæ, which are marked longitudinally along the summit by faint undulating striæ. The edges of the branches are non-poriferous and smooth, or very indistinctly striate, obtuse, but with a narrow salient margin indicating the position of the epithecal lamina.

The largest specimen found was 160 mm. long and 85 mm. wide; the branches are somewhat flexuose, about 4 to 5 mm. broad, and from 2 to 3 mm. thick. This form may be compared with *P. acuta*, *Hall*, from the Trenton Group of New York.

Locality and position. Soldiers' Home Quarries, Fair Haven. Clinton Group.

XII. PACHYDICTYA BIFURCATA, VAR. INSTABILIS, VAR. N.

(*Plate* XV, *Fig.* 10.)

Frond known only by fragments 30 to 40 mm. long and broad, branching dichotomously at wide and variable angles. The branches from 3 to 5 mm. wide and from 1 to almost 2 mm. thick; the surface uneven, more or less tuberculated, the tubercles low but generally distinct, without evident arrangement, about 4 tubercles in a distance of 80 mm, measured longitudinally.

The cells are oval, from 6 to 7 occupying a length of 2 mm, usually nearer the latter number, and from 8 to 9.6 rows occupying the same distance in breadth. The non-poriferous edges narrow in the specimens examined.

Whether this form is distinct from the last one, it is difficult to tell. Where there are so many species of a genus, occurring in such abundance, their form is usually very variable, and the distinctions between species are not always well defined. Judging from the specimen at hand, it is difficult and perhaps impossible to distinguish between the forms specifically, and intermediate forms seem to occur.

Locality and position. Brown's Quarry, Clinton Group. The species occurs here in all its forms apparently. The extreme, nodulated or tuberculated forms, which are separated here as a variety predominate.

XIII. PACHYDICTYA TURGIDA, *sp. n.*

(*Plate* XV, *Fig.* 11; *Plate* XVII, *Fig.* 11.)

Fronds variable, branching dichotomously at angles from 30° to 50°; branches more or less thickened, the edges inclined to be obtuse with a salient line along the epithecal lamina, the margin non-poriferous. Cells oval, 12 in a distance of 5 mm, measured along the longitudinal series, 16 series in the same distance in breadth. Two or three faint flexuose lines are found on the ridges separating the series.

The surface is tuberculate; the tubercles are of variable distinctness, and are arranged in something like order, from 4 to 5 in a distance of 10 mm. The tissue in the tubercles becomes very thick, the arrangement of the cells is somewhat disturbed and their number reduced.

The largest fragment at hand is 55 mm. long and 35 mm. broad. The branches vary from 6 to 9 mm. in width, and from 1.8 mm. to 3.5 mm. in thickness.

Name signifies *thick, swollen,* referring to the thickened fronds. This form may be compared with *P. fenestelliformis, Hall,* as identified by Mr. E. O. Ulrich, from the Cincinnati Group of Illinois.

Locality and position. Soldiers' Home Quarries, Fair Haven, Clinton Group.

XIV. PACHYDICTYA OBESA, *sp n.*.

(*Plate* XV, *Fig.* 12.)

The structure of this species is very similar to the last, but the fronds are broader, apparently undivided, and usually thicker, forming coarse, often undulating or folded fronds. Tubercles much more distinct, with a more decided tendency for arranging themselves in series, 4 to 5 in a distance of 10 mm. Tangential sections show that the number of cells is decreased in the tubercles by the turgescence of the surrounding laminæ, or by the entire suppression of cells. One of the largest fronds at hand is a fragment 65 mm. long, 37 mm. wide and 5 mm. thick. Some specimens are not so thick, but still thick enough to attract attention to this feature. It may be compared with *P. gigantea, Ulrich,* from the Cincinnati Group of Illinois.

Name signifies, *very thick and swollen, fat.*

Locality and position. Soldiers' Home Quarry, Clinton Group.

CYSTODICTYONIDÆ, Ulrich.

Zoaria consisting of two or more layers, grown together along their epithecal membranes. Cell apertures with a crescentic lip. Interstitial spaces occupied by vesicular tissue, which in the matured stage is almost obliterated by a secondary deposit of sclerenchyma, apparently perforated by minute, vertical, communicating canals. Margins of zoaria non-poriferous. (Ulrich, Am. Pal. Bry. April, 1884.)

GENUS RHINOPORA, Hall.

Zoaria consisting of two laminated expansions, grown together along their epithecal membranes; the margins are non-poriferous. The cell apertures are strongly raised above the surface in little papillæ or pustules. The aperture itself is quite small and usually appears more or less irregular in form, suggesting the crescentic lip so characteristic of the *Cystodictyonidæ* and *Fistuliporidæ*. The interstitial tissue, if any, seems to have been obliterated by the secondary deposit of sclerenchyma.

XV. RHINOPORA VERRUCOSA, *Hall.*

(*Plate* XV, *Fig.* 13; *Plate* XVII, *Fig.* 12.)

Rhinopora frondosa, Hall and Whitfield, 1875, Ohio, Pal. Vol. II.
Escharina (?) distorta, James, 1879. The Paleontologist, No. 3.
Rhinopora venosa, Spencer, 1884, Niagara Fossils, St. Louis Acad. Science, Vol. IV, No. 4.
Cf. Rhinopora curvata, Ringueberg, Bull, Buffalo. Soc. Nat. Sc., Vol. V, No. 1.

Fronds forming thin expansions, the defining margins being sharp and distinctly non-poriferous. Specimens usually occur in the form of fragments, smaller pieces of which appear flattish, and some pieces of even fair size may be found with only a moderate amount of curvature. However, when broken from the solid rock, parting along the epithecal membranes, expansions may be followed for 30 mm. or more through the rock, contorted and curved in almost every possible manner. Proper branching does not take place, but the outlines of the fronds are often quite irregular. The character of the base of the frond is unknown. The cells are arranged in diagonally intersecting rows which may be quite straight for a moderate distance, but usually are somewhat curved. This arrangement may be perfectly maintained over quite a large portion of the surface, but frequently is perfect only in small patches, the rows of which do not perfectly join each other, on account of the introduction of new rows, the sudden curvature of a series of rows, or on account of the disturbing influences of the structure next to be described. Between the cell rows at variable distances over the frond are distributed a number of raised lines which are more or less connected with each other and have the appearance of a branching structure trailing over the surface of the frond. These may become quite conspicuous and form a marked feature of the frond, but they do not seem to have any very intimate connection with the rest of the frond. This they very frequently show by entirely weathering away from the surface of the frond. The place they occupied is then marked by a groove which becomes quite conspicuous in the specimens which were characterized by large raised lines. These raised lines extend along the grooves between the cell rows usually including and resting upon the inner half of the cells between which they extend. Usually they leave the arrangement of the cells unaffected, but the arrangement of the rows may be more or less disturbed in crossing these lines. At the junction of the raised lines, especially where several lines meet, the cells are apt to be more separated at this point than elsewhere on the frond; the cells then frequently become of somewhat larger size, are more prominent, and form slightly elevated clusters of moderate size, over the surface of the frond, which sometimes occur at quite regular intervals and form conspicuous features of the frond. When the raised lines in such specimens were quite narrow and then weathered away, these low elevations are still more conspicuous. The center of the elevations is frequently marked by an irregular, non-celluliferous portion where the lines meet; these spaces then may suggest maculæ. The prominent surrounding cells of the elevated parts are frequently crowded back upon each other for a short distance by the dividing ridges and then also are more inclined to form conspicuous elevations. The apertures of the cells are produced in the form of round papillæ above the surface of the frond. The mouth is situated at the very summit of the papillæ, but may appear more or less lateral by the unequal wearing away of the cells. Near the base on one side of the cell may be found a small depression, the precise nature of which is unknown. It may have had some connection with the interior of the frond, but such connection has not been established. No interstitial tissue has been satisfactorily determined. The cells vary from 50 to 60 in the distance of 25 mm. In *R. tubulosa*, *Hall*, they are said to be more crowded, numbering from 80 to 85 in the same distance.

This species is seen to be quite variable, but there is no difficulty at all in tracing the connection of the different forms in any collection which contains a large number of specimens in a good state of preservation. As might be expected, its distribution is also quite wide, extending from New York to Ontario and Ohio, and being found both in the Niagara shales and in the Clinton Group.

Locality and position. Brown's Quarry, Soldiers' Home Quarries, Centreville, Fair Haven, Todd's Fork, Clinton Group.

FISTULIPORIDÆ, Ulrich.

This family is closely allied to the *Cystodictyonidæ*, from which it differs in the absence of non-poriferous margins and in having no secondary deposit obscuring the presence of the interstitial cells, or at least, when present, being quite superficial.

GENUS LICHENALIA, Hall.

Zoaria composed of a single layer of cells, the epithecal side being concentrically wrinkled, the wrinkles being supplemented by secondary finer concentric striæ; when the epithecal membrane is translucent, the bases of the cells may be frequently seen in the form of short, radiating striæ. Cells with a crescentic lip at the aperture which is continued into the tube of the cell in the form of two longitudinal inflections of the cell walls. Interstitial cells always present, separating the cells.

XVI. LICHENALIA CONCENTRICA, *Hall.*

(*Plate* XVII, *Fig.* 10.)

No specimens of this species have been found in my own collections, but it is represented by several specimens in the cabinet of Dr. L. B. Welch. The following short description of this species is therefore added.

Zoaria forming circular flattened expansions, often 130 mm. in diameter, celluliferous on one side only, the arrangement of the cells being disturbed in some varieties by the presence of maculæ. Cells separated by angular interstitial cells. Non-celluliferous face wrinkled concentrically.

Locality and position. Clinton County, Clinton Group, collection of Dr. L. B. Welch.

CERAMOPORIDÆ, Ulrich.

Zoaria usually incrusting, sometimes ramose with hollow branches, or flabellate. Cell apertures triangular or ovate, with a prominent and arched lip usually on one side. (Ulrich, Am. Pal. Bry.)

GENUS CERAMOPORA, Hall.

Usually incrusting. Cells angular, with the lip strongly arched, the aperture oblique; cells radiating from one or more centers. (Ulrich, Am. Pal. Bry.)

XVII. CERAMOPORA EXPANSA, *James.*

(*Plate* XVII, *Fig.* 13.)

Alveolites expansa, James, 1879, Paleontologist, No. 3.

"Corallum, a flat or undulating expansion, irregular in outline, 6 inches or more in diameter, varying in thickness from less than one to over two lines. Corallites very oblique and more or less sinuous in their direction from the base or central axis to the surface. Calices very narrow, slightly curved, elongated slits, showing, generally, when a little weathered, a tooth-like projection in the middle of the upper lip, and arranged sometimes in series of short curved rows in a more or less alternating manner. About 4 calices in the space of a line. Walls of corallites thick.

"Although the specimen from which this description is made was found spread over the surface of a rock—from which it readily scaled off—it is not certain that it was *encrusting*, as there is an appearance of something like a central axis from which the corallites grew in different directions to opposite surfaces, in a very oblique manner; portions of the side next the rock show calices similar to the other side, but not so distinct, as it is mostly covered by, apparently, indurated clay." (James. *loc. cit.*)

Dr. L. B. Welch very kindly showed me the type specimen in his cabinet. The specimen is very unsatisfactory. The cell apertures were seen to have a strongly arched lip on one side, and were arranged in diagonally intersecting rows, about 5 cells in a length of 2 mm. I should be unwilling to attempt any further statements concerning it, and so have repeated the original description. Its general aspect seemed to be that of a much worn fragment of some species of *Ceramopora*.

Locality and position. Clinton Group, Clinton county; collection of Dr. L. B. Welch.

MONTICULIPORIDÆ, Nicholson.

Zoarium with tubular cells, which are thin-walled and polygonal below, above they are bent more decidedly towards the surface, are of nearly equal size throughout, more or less thickened and rounded, but never lipped nor separated by vesicular tissue. Zoaria usually ramose, occasionally frondose, or forming flat circular or irregular expansions; never composed of two distinct layers of cells entirely separated by epithecal membranes.

GENUS PRASOPORA, Nicholson and Etheridge.

Zoarium forming a hemispherical mass or a thin expansion, with a wrinkled epithecal membrane on the lower surface. Cells cylindrical or more or less prismatic, lined on one side with cystoid diaphragms.

XVIII. PRASOPORA PARMULA, *sp n.*

(*Plate* XV, *Fig.* 14; *Plate* XVII, *Fig.* 14.)

Zoaria forming thin, flattened expansions which are lined by a wrinkled epithecal membrane on the lower surface; circular when young, later becoming more irregular in outline. Typically the lower

surface is concave, corresponding to the convex outline of the upper surface. Cells of about the same size, occasionally a few are slightly larger in size, but form no distinct feature in the growth of the zoarium. Cell apertures polygonal, but rounded and almost circular, having a tendency to arrange themselves in rows. In the space left between the outlines of four cells is usually an angular interstitial cell not always readily recognized at the surface under a low magnifying power. Cells with cystoid diaphragms along one side, the ends of the same gradually becoming attenuated and almost meeting on the other side of the wall, thus almost encircling the cells. In addition to cystoid diaphragms a number of straight diaphragms are found, which run from the middle of the cystoid diaphragms to the opposite wall. The interstitial cells are also crossed by straight diaphragms, which. however, are far more numerous than those of the regular cells, being usually twice as many or even more.

Cells, about 8 or 9 in a distance of 2 mm; in one specimen about 18 straight diaphragms are found in the length of an interstitial cell, 9 cystoid diaphragms are found in the adjoining cell, most of which are connected with a straight diaphragm also belonging to this cell; since the thickness of this specimen is about 1 mm, a very fair idea of the relative importance of these tissues may be formed. Expansions vary from 20 mm. to 33 mm. in diameter. The name signifies *a little shield*.

Locality. and position. Huffman's Quarry, Beavertown Marl; Soldiers' Home, Clinton Group. Todd's Fork, in the upper iron-bearing portions of the Clinton Group; this iron-containing layer, which is here several feet thick, contains almost all the characteristic fossils of the Beavertown marl.

GENUS MONOTRYPELLA, Ulrich.

"Ramose, smooth or tuberculated. Cells apparently of one kind only. Walls very thin in the axial portion of the branches. but thicker in the peripheral region. Diaphragms straight. No spiniform tubuli." (Ulrich, Am. Pal. Bry.) The following species is provisionally referred here on account of the apparent absence of interstitial cells.

XIX. MONOTRYPELLA CONFLUENS, *sp. n.*

(*Plate* XVI, *Fig.* 4; *Plate* XVII, *Fig* 15.)

Zoaria irregularly ramose, branches varying from 5 mm. to 11 mm. in diameter, usually forming coarse, gnarled growths by the irregular confluence of several branches, which are very characteristic of this species. Cells vary from 9 to 11 in a distance of 3 mm; where the surface is well preserved, the margins of the cells are seen to be circular and to be distinctly raised above the surface of the branch. The margins sometimes touch each other on one or more sides, but are just as frequently entirely free and distinct, and never are polygonally compressed. The interstitial spaces left between the raised margins of the cells sometimes have the appearance of small interstitial cells, but usually they appear simply as depressed areas. In worn specimens the raised margins of the cells can not be detected and the inter-cellular spaces then appear simply as thickened cell walls, separating the cells. Tangential sections give no evidence of interstitial cells in such cases, and in longitudinal sections the cells appear to be of one kind only. The cell walls in tangential sections near the surface appear very thick, but only a slight distance from the surface they are seen to be very thin. Straight diaphragms are developed in moderate numbers and are somewhat more numerous towards the surface, but the distinction between the mature and immature portion does not seem to be very great. About 9 diaphragms occur in one of the sections in a distance of 3 mm; the number naturally would vary considerably however. In some specimens in which the surface is free from all sediment, operculate diaphragms seems to extend across the cells a short distance below the surface of the specimen. Some specimens also show low elevations about 3 mm. distant from each other, in which the number of cells seems somewhat reduced. The name refers to the characteristic gnarled expansions formed apparently by the growing together of branches, the latter becoming *confluent.*

Locality and position. Soldiers' Home, Clinton Group.

GENUS CALLOPORA, Hall.

" Ramose to sub-frondescent, smooth or tuberculated. Cell-tubes cylindrical, their apertures often closed by an operculum, with a very small central perforation, from which usually radiate small ridges. Interstitial cells, more or less numerous, sometimes completely isolating the proper zoæcia. Diaphragms numerous. Spiniform tubuli and cystoid diaphragms wanting." (Ulrich, Am. Pal. Bry.) The following species are provisionally referred here on account of an apparently similar relation between cells and interstitial cells.

XX. CALLOPORA MAGNOPORA, *sp. n.*

(*Plate* XVI, *Fig.* 5; *Plate* XVII, *Fig.* 16.)

Zoaria branching at intervals of about 15 mm; branches from 6.5 to 8 mm. in diameter, rather irregular in form and often with low tubercles of no marked characteristics, and which may be entirely absent. Cells about 8 in a distance of 3 mm. Cell apertures sub-circular, the margins not distinguishable at the point of contact, but distinct and elevated along the rest of the cells, apparently enclosing interstitial cells, these appearances obscured by abrasion. Tangential sections seem to give better evidence of interstitial cells, these being smaller, irregular, rather fewer in number, and more or less surrounding the more circular cells. In longitudinal sections the interstitial cells may apparently be also detected, being narrower cells with somewhat more numerous diaphragms. In one specimen there were 10 diaphragms in a length of 1 mm. in the cells, in the interstitial cells 13 or 14 were found.

This species is readily distinguished from the last by the larger size of the cell apertures, being about one and a half times the size of that species. When the number of the cells is approximately the same this may be accounted for by the fact that, whereas in the former species there is a considerable space left between the margins of the cells, in this species they are united into one cell wall, indistinguishable at the surface. The number of diaphragms is also much greater in this species. However, if the presence of interstitial cells has been correctly determined, this offers no ready character for determination, since abraded specimens and even moderately well preserved specimens are scarcely distinguishable by superficial examination in appearance from the last species. The name signifies *large pored or celled.*

Locality and position. Centreville, Soldiers' Home Quarry, Clinton Group.

XXI. CALLOPORA OHIOENSIS, *sp. n.*

(*Plate* XVI, *Fig.* 6; *Plate* XVII, *Fig.* 17.)

Zoaria more regular in formation than the two species last described, branches varying from 2.5 mm. to 5 mm. in diameter. Cells apparently of two kinds. The true cells are of nearly uniform size, subcircular, and stationed apart at somewhat regular intervals, from 11 to 13 occupying a distance of 3 mm. Separating these cells and usually completely isolating them are a number of interstitial cells very variable in size, even in the same part of the branch, some being larger and some smaller than the true cells, but usually of the same average size. The true cells are usually in our specimens filled more or less with sediment and so are more readily distinguishable. Tangential sections show this feature very plainly. Longitudinal sections do not show any difference in size between the true and the interstitial cells, nor is there any appreciable difference in the number of the straight diaphragms; these features will distinguish it readily from *C. elegantula*, *Hall.* It will be remembered that only under favorable circumstances was any difference noted in the number of diaphragms in the last species. The number of diaphragms in general is but slightly greater than in that species.

Locality and position. Centreville, Clinton Group.

PLATE XV.

Fig. 1. *Phylloporina angulata, Hall:* the small form for which the name *P. Daytonensis* was suggested by Hall and Whitfield

Fig. 2. *Hemitrypa Ulrichi, n. sp:* a part of a frond showing the infundibuliform structure.

Fig. 3. *Clathropora frondosa, Hall:* a part of a frond showing the point of articulation with some basal structure.

Fig. 4. *Clathropora Clintonensis, Hall and Whitfield;* fragment of a frond showing a somewhat similar provision for articulation.

Fig. 5. *Ptilodictya expansa, Hall and Whitfield:* a part of a typical frond from Todd's Fork, Clinton County.

Fig. 6. *Phænopora magna, Hall and Whitfield:* a fragment showing the surface.

Fig. 7. *Phænopora fimbriata, James;* a typical frond, parted along the epithecal membranes; branches frequently found with a looser arrangement.

Fig. 8. *Pachydictya emaciata, n. sp;* the type specimen.

Fig. 9. *Pachydictya bifurcata,* (*Van Cleve*) *Hall;* a large frond showing in places a pseudo-anastomosis of the branches.

Fig. 10. *Pachydictya bifurcata, var. instabilis, n. var;* one of the extreme forms.

Fig. 11. *Pachydictya turgida, n.sp,* a typical form.

Fig. 12. *Pachydictya obesa, n. sp;* the basal portion of a frond, its articulating end not discovered; the frond usually widens considerably above and is often decidedly undulating.

Fig. 13. *Rhinopora verrucosa, Hall;* a, a fragment showing raised branching lines; b, a similar specimen in which weathering has caused the same to appear as depressed veins; c, a specimen in which the cells at the junction of the veins have become somewhat more prominent, forming low tubercles.

Fig. 14. *Prasopora parmula, n. sp;* the type specimen.

PLATE XVI.

Fig. 1. *Phænopora platyphylla, James;* a frond, parted along the epithecal membrane.

Fig. 2. *Phænopora magna, Hall and Whitfield;* a frond, parted along the epithecal membrane.

Fig. 3. *Phænopora multifida,* (*Van Cleve*) *Hall;* a typical specimen from the collection of Mr. Geo. Caswell; parted along the epithecal membrane.

Fig. 4. *Monotrypella confluens, n. sp;* a, a branch; b, a typical gnarled expansion.

Fig. 5. *Callopora magnopora, n. sp;* a branch.

Fig. 6. *Callopora Ohioensis, n sp;* a branch,

PLATE XVII.

Fig. 1. *Phylloporina angulata, Hall;* a, celluliferous side; b, non-celluliferous side; c, a tangentitial section.

Fig. 2. *Hemitrypa Ulrichi, n. sp;* a, the network covering the celluliferous side; b, the non celluliferous side; c, a tangential section.

Fig. 3. Clathropora frondosa, Hall; a tangential section.

Fig. 4. Clathropora Clintonensis, Hall and Whitfield; a tangential section.

Fig. 5. Ptilodictya expansa, Hall and Whitfield: a, a part of the surface; b, a tangential section.

Fig. 6. Phænopora platyphylla, James: a, a part of the surface; b, a tangential section.

Fig. 7. Phænopora magna, Hall and Whitfield; a part of the surface.

Fig. 8. Pachydictya emaciata, n. sp.; a part of the surface.

Fig. 9. Pachydictya bifurcata, (Van Cleve) Hall; a, a part of the surface; b, a tangential section.

Fig. 10. Lichenalia concentrica, Hall; a part of the surface, where it has been worn or emaciated, showing the angular intercellular spaces. Copied from Hall, Geol. Surv. Ind. 11th Rep., Plate 5, Fig. 6.

Fig. 11. Pachydictya turgida, n. sp.; a tangential section.

Fig. 12. Rhinopora verrucosa, Hall; a tangential section.

Fig. 13. Ceramopora expansa, James; a few cell apertures, as shown by a part of the surface of the type specimens. From a sketch taken from the type specimen in the collection of Dr. L. B. Welch.

Fig. 14. Prasopora parvula, n. sp.; a, a tangential section; b, a vertical section.

Fig. 15. Monotrypella confluens, n. sp.: a. a part of the surface; b. a tangential section; c. a vertical section.

Fig. 16. Callopora magnopora, n. sp.: a. a part of the surface; b. a tangential section; c. a vertical section.

Fig. 17. Callopora Ohioensis, n. sp.: a. a part of the surface; b. a tangential section; c. a vertical section.

Fig. 1.

Fig. 2.

PLATE X.

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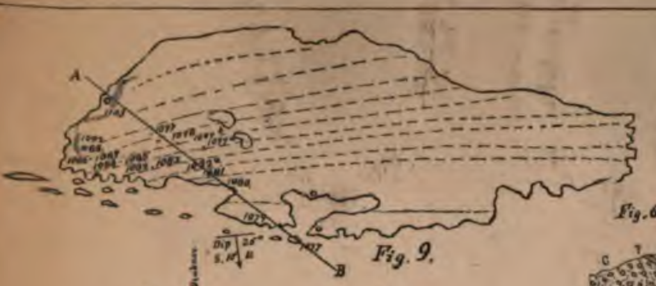

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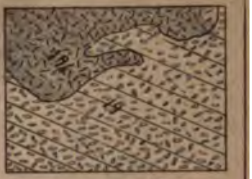

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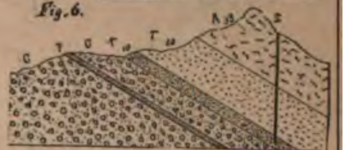

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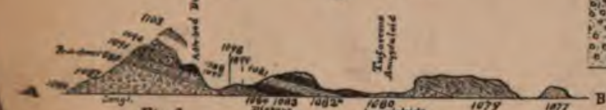

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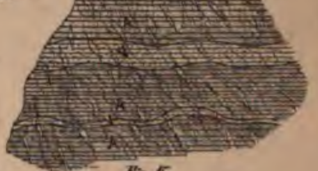

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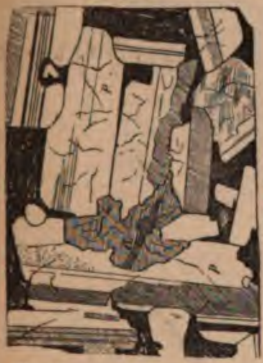

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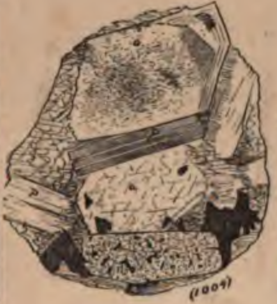

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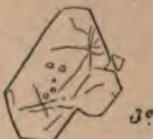

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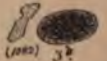

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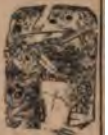

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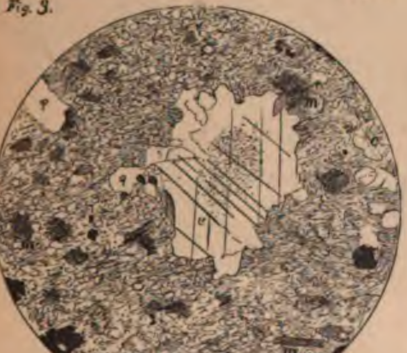

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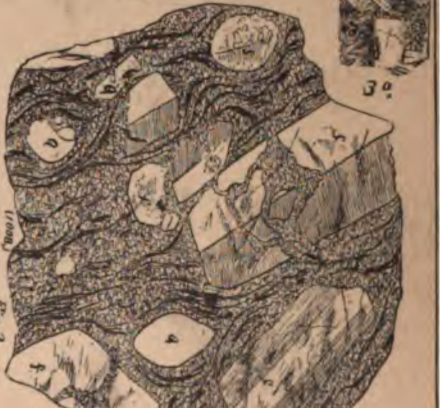

Fig. 2.

Herrick.

PLATE XI.

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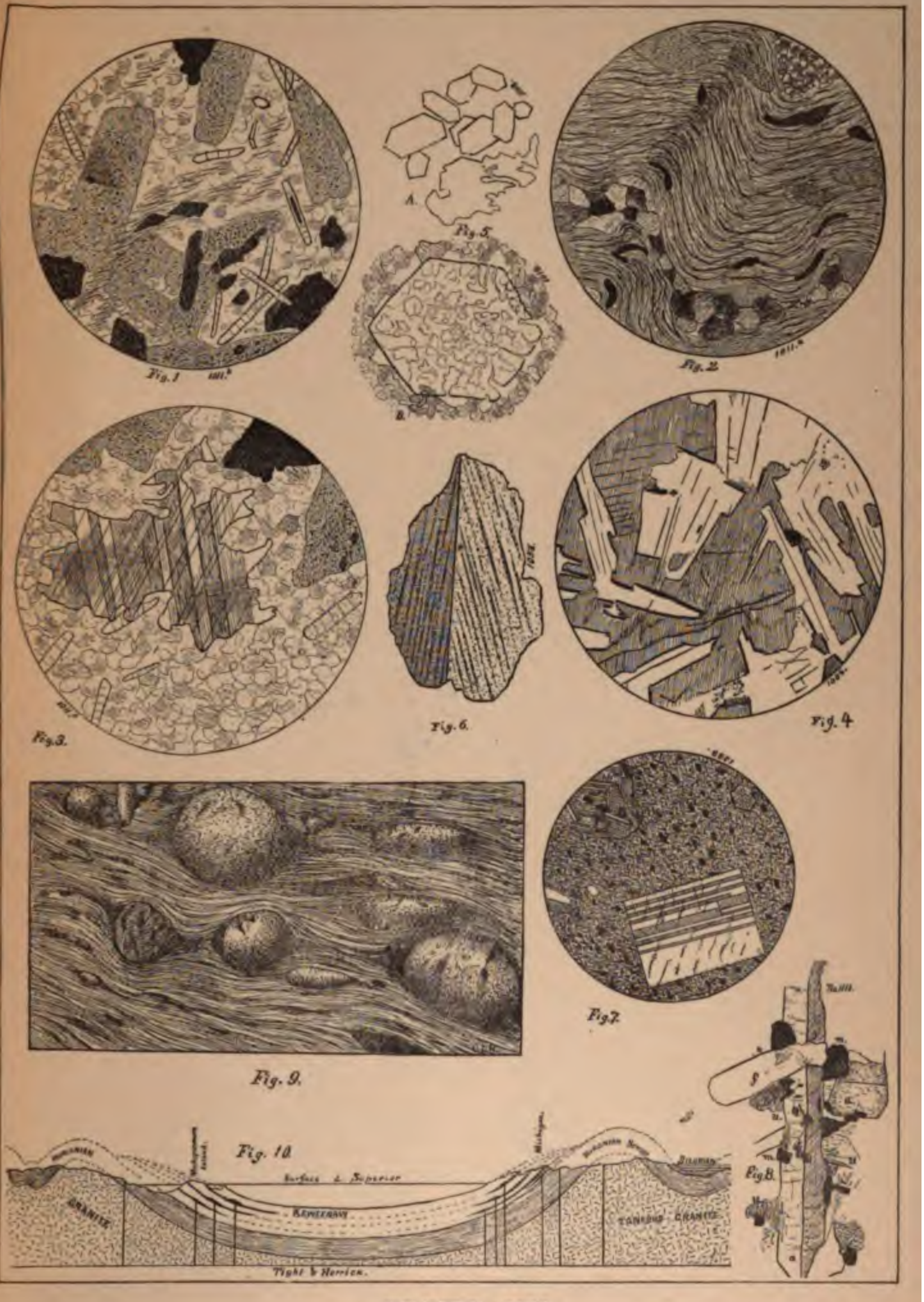
Fig. 1
Fig. 5
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Fig. 10
HURONIAN
Surface L. Superior
GRANITE
KEWEENAW
SILURIAN
GRANITE

PLATE XII.

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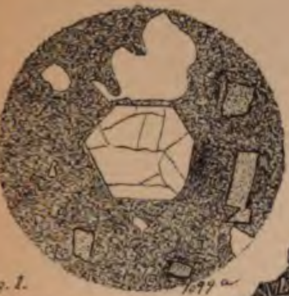

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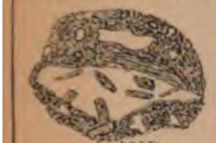

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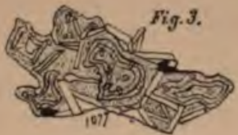

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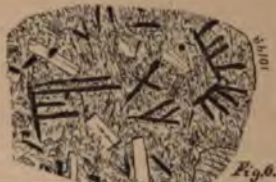

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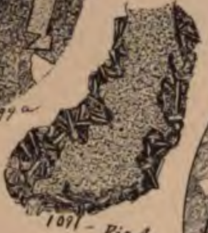

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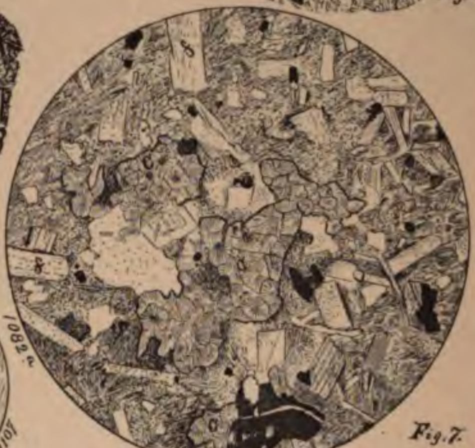

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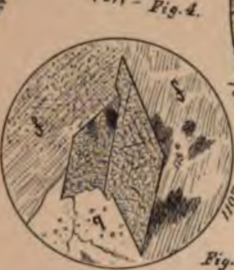

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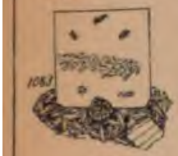

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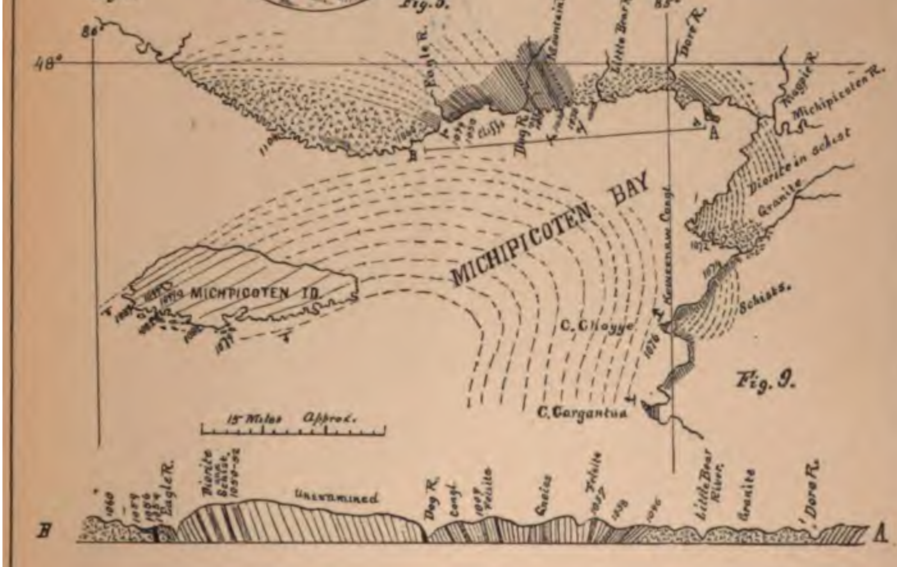

Fig. 9.

Janes & Herrick.

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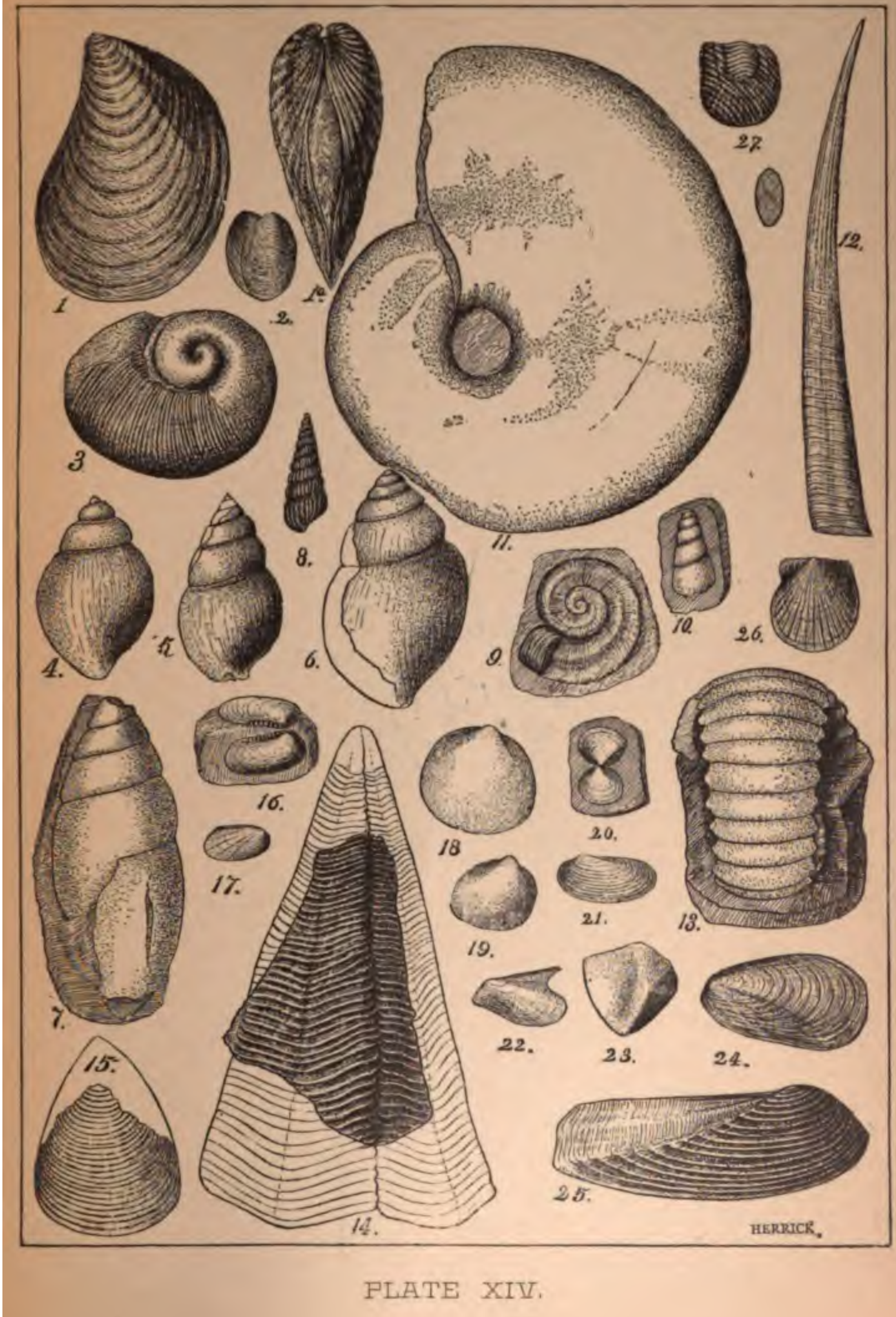
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PLATE XIV.

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BULLETIN

OF THE

Scientific Laboratories

OF

DENISON UNIVERSITY,

EDITED BY

C. L. HERRICK, DEP'T. OF GEOL. AND NAT. HISTORY.

VOLUME III.

GRANVILLE, OHIO, APRIL, 1888.

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VOL. III, PART I.

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THE CLINTON GROUP OF OHIO.—PART IV.

BY A. F. FOERSTE.

CHEMICAL GEOLOGY.

The Silurian rocks of Ohio open with the Cincinnati Group. This group is composed of a series of limestones interbedded with shales or clay. Neither the limestones nor the shales are magnesian in character, the carbonate of magnesia rarely exceeding six per cent. The amount of silica, however, varies greatly. The lower beds of limestone contain from ten to twenty-five per cent. of silicious matter; there is a corresponding diminution of the amount of the carbonate of lime. The upper part of the series, however, contains very little silicious matter, usually less than two per cent.; the carbonate of lime, however, becomes a much more important constituent, averaging ninety per cent. The interbedded shales differ from the limestones chiefly in the amount of silica contained, there being a corresponding diminution of the carbonate of lime. Thus the amount of silicious matter in the shales varies between fifty-five and eighty per cent.; the amount of the carbonate of lime, between four and twenty per cent. The shales also contain more alumina than the limestones, but the striking difference is evidently the amount of silicious matter contained. In one of the lower series of shales belonging to the Cincinnati Group, but found in Covington, Kentucky, the amount of silicious matter is somewhat less, forty-three per cent., and the amount of the carbonate of lime is much greater, forty-seven per cent. Otherwise the chemical peculiarities of the shales are quite uniform, differing in this respect from the interbedded limestones.

In Preble county, near Fair Haven, a sandy rock intervenes between the Cincinnati and the Clinton Group. It is about two feet thick. In a fragment of rock lying near by and apparently of the same origin, there was the impression of a large aviculoid shell. In Clinton county, near Wilmington, there is another series of sandy stone between the Cincinnati and the Clinton Groups. The lower part consists of quite heavy stone, about five feet of it are exposed, although there may be more. This contains annelid teeth near its upper courses. These sandy stones are referred to the Medina Group, although there is no paleontological proof to warrant this reference. They do not exist at all in the numerous exposures near Dayton.

Several years ago my friend, Mr. A. B. Knerr, at that time assistant in the chemical laboratory of Wittenberg College, made for me some analyses of the rocks found at Huffman's quarry, southeast of Dayton, and also of one specimen from the Clinton Group, at a hill known as Camp Corwin, east of Dayton. The result is shown in the following table:

Chemical Analysis of Clinton and Niagara Limestone.	Chemical Substance Contained.	Niagara Shale.	Dayton Limestone.	Beavertown Marl.	Clinton Dark Red.	Clinton Light Red.	Clinton Dark Green.	Camp Corwin Clinton.
Relative amounts of Calcium and Magnesium Compounds.	$CaCo_3$	46.22	93.23	------	97.75	97.83	65.14	------
	CaO	------	------	26.36	------	------	------	35.03
	CO_2	------	------	31.27	------	------	------	25.03
	MgO	------	------	14.11	------	------	------	.53
	$MgCO_3$	23.38	4.00	------	.22	.75	11.15	------
Sand and Clay Ingredients.	SiO_2	17.83	1.95	18.27	1.03	.28	8.27	6.03
	Al_2O_3	8.70	------	5.55	------	------	2.86	2.13
Amount of Iron Entering into the composition.	$FeCO_3$	2 60	.43	------	.60	.21	3.33	------
	FeO	------	------	3.48	------	------	------	1.29
	Fe_2O_3	------	------	------	------	------	------	28.66
	FeS_2	------	------	------	------	------	6.56	------
Miscellaneous Compounds.	K_2O	1.06	.37	.72	.22	.24	1.19	.34
	P_2O_5	------	trace	------	trace	trace	trace	.87
Water contained not calculated.	TiO_2	------	------	.22	------	------	------	------
	Na_2O	trace	------	------	------	trace	------	------
Total	------	98.88	99.98	99.98	99.82	99.31	98.50	99.91

Of the specimens here analyzed, those marked "dark red" and "light red" represent the typical forms of Clinton as they occur at Huffman's quarry. With these may be compared the following analyses of Clinton rocks from other parts of the state. Centerville, Montgomery county: $CaCO_3$, 86.30; $MgCo_3$, 11.34; SiO_2, .85. Eaton, Preble county: $CaCO_3$, 85.21; $MgCo_3$, 13.56; SiO_2, .35. Brown's quarry, New Carlisle, Clarke county: $CaCO_3$, 95.60; $MgCO_3$, 3.93; SiO_2, not discovered in the analysis, if present at all, then only in inappreciable quantities. Ludlow Falls, Miami county: $CaCO_3$,, 91.30; $MgCO_3$, 6.51; SiO_2, .80.

Comparing the limestone of the Clinton Group with those of the upper part of the Cincinnati Group, we find a close resemblance in the small amount of silica present in each. The magnesium carbonate, however, which in both the shales and limestones of the entire Cincinnati Group was present only in inconsiderable amounts, now begins to be a very variable quantity, varying from less than one per cent. to almost fifteen per cent. This variation causes a compensating change in the amount of calcium carbonate present. It will also be noticed that the central locality, near Dayton, has the least amount of magnesium carbonate, but that the amount increases in all directions, moderately so towards the northeast, Brown's quarry, and the northwest, Ludlow Falls; but markedly so towards the south, Centreville, and the west, Eaton. In other words there seems to be a slight tendency of the Clinton Group, beginning with Dayton as the center, to become more magnesian towards the circumference of the exposed parts.

The same thing is true, but in a far more marked and satisfactory sense, of the Dayton limestone. Here again the series of quarries of which Huffman's quarry is the center, contain the least amount of magnesium carbonate. At a distance these exposures become more and more magnesian until finally they can no longer be told from the Niagara shales above.

But there is not only an increase in the amount of dolomitisation laterally, but also vertically. To be sure, in Huffman's quarry this change is very sudden. There is a fairly sharp line between the Clinton Group and the Beavertown marl. At Todd's Fork, near Wilmington, Clinton county, they gradually run into each other, and there is a commingling of fossils. The Niagara shale at Huffman's quarry is also quite distinct from the Dayton limestone beneath. But at Centerville, and numerous other places throughout the state, there is quite a gradual change from one into the other. Whatever may have been the cause of the increase of the carbonate of magnesium, it seems to have originated outside of the special area here described. It began to operate in the Clinton Group. At Todd's Fork the change was rather gradual, but at Huffman's quarry, after dolomitisation elsewhere had became quite advanced, it seems to have come suddenly, remained long enough to deposit the thin Beavertown marl, and then to have retreated again, giving way to the formation of quite a pure limestone again. Meanwhile, on the outskirts of this area the dolomitic character was still maintained, and a second advance of the causes leading to dolomitisation took place, gradual at the outskirts, quite sudden at Huffman's quarry. After this second advance of the cause which may have given rise to dolomitisation, it became permanent, the silicious elements which had accompanied its earlier advance became less, and the comparative amount of dolomite increased until in the Springfield and Guelph, or Cedarville strata, the rock had become a typical dolomite.

It is evident, therefore, that the problems as to the cause of the rapid succession of the limestones and shale or clays of the Lower Silurian is a different one from that of the cause of the insertion of the Beavertown marl and the Niagara shales in the Upper Silurian Group of Ohio. While those of the Upper Silurian were part of a general process of dolomitisation, more or less gradually infecting the sediments of the series, those of the Lower Silurian evidently are the result of a much more rapid and much more frequent alteration. Both of these processes remain still to be explained. Much has been written; it may be equally valuable to examine the question without any special theory in view. The chemical relations of the Clinton Group to the rocks above and below can at least be well established.

It remains to note a few points about the relative amount of iron present in the Clinton Group. In the two analyses from Huffman's quarry noted "light red" and "dark red" it will be noticed how small a variation of the amount of iron present is sufficient to make a marked difference in appearance to the eye. The Camp Corwin specimen is from the uppermost layers of the Clinton Group, at the locality mentioned and is a picked specimen, the usual amount present in the same layers being much less. The amount of iron becomes greater as well as far more regular in the upper courses of the Clinton Group at Todd's Fork, here becoming oolitic in places. Farther south from this point it increases until it reaches some importance in the southern counties.

The specimen from Huffman's quarry marked "dark green" is a fragment showing localized features of the ordinary limestone of that locality, of small extent, usually existing only as little, often far distant, patches. In the discussion of the chemical character of the rocks here examined the analyses made by Dr. T. G. Wormley, and published in the various volumes of the Ohio Geological Survey have been constantly before my eyes.

STRATIGRAPHICAL GEOLOGY.

Stratigraphically the Clinton Group of Ohio presents no marked subdivision except that of the Beavertown marl, which occurs at Huffman's quarry, and also at Todd's Fork, but not as a marked subdvision. The top of the Clinton at Centreville and the Soldiers' Home quarries, is composed of a few inches of clayey sediments, which present a much larger number of specimens of certain species than are found in the rocks below. These are: *Orthis hybrida*, *O. elegantula*, *G. fausta*, *O. Daytonensis*, *Triplesia Ortoni*, *Calymene Vogdesi* (the larger forms). *Rhinopora frondosa*, and *Homotrypa confluens*. But this seems to be a mere local variation.

A comparison of the Ohio Silurian with the corresponding strata of Indiana is at the present date difficult, owing to the fact that no connected plan of work seems to have been followed in that state, so that observations made are apt to have only very local value, and different writers apparently apply different values to the same stratigraphical names. Careful paleontological observations with the exception of the Waldron beds, are also lacking. Lithological features alone, unfortunately, are so often deceptive that not much reliance can be placed upon them. However the following conclusions seem fairly well drawn.

The Lower Silurian series of Indiana have been well determined. In places, especially in Decatur and the more southern counties, the base of the Upper Silurian is formed by a sandy rock, varying from a few inches to several feet in thickness, and corresponding in position to with those of Fair Haven and Todd's Fork, in Ohio—the so-called Medina.

The top of the Upper Silurian of Indiana has also been well determined. It consists of the highly magnesian rock known as the Guelph, in Canada, and the Cedarville, in Ohio. It has been identified in Grant, Madison, Delaware, and Randolph counties (13th Rep. Ind. Geol. Surv.); across the line it occurs again in the north of Preble county, Ohio.

In Ohio the Springfield beds have been identified at Eaton, Preble county; and the West Union beds seem to be entirely lacking. The Springfield strata are in reality very closely allied to the Cedarville strata, and are distinguished mainly by the great abundance of the brachiopod, *Petamerus oblongus*, and by the fact that it usually shows a more decided tinge of blue. The blue magnesian rocks immediately to the south of the Guelph series already mentioned may safely be referred here.

In Ohio the Eaton beds extend south, reaching to a distance within four miles of the Clinton exposures at Fair Haven. About two miles north of the latter, the intervening portion is seen to contain limestone beds, and also some cherty layers, one of which is well marked, about nine inches thick, and contains numerous specimens of *Atrypa reticularis*. Now *if* the cherty layers here may be considered fairly equivalent with the cherty beds usually found beneath the Waldron fossil beds of Indiana, then the Waldron beds may fairly be considered the equivalent of the Upper Niagara shales of Ohio and perhaps to contain sufficient association with the Springfield beds to give its fauna a tinge of the facies of the Guelph. The part below the cherty beds in Indiana would then contain the materials recognized in Ohio as Clinton, Dayton, and perhaps the lower part of the Niagara shale strata. The Clinton has been reported from various parts of Indiana, but until the paleontological proofs for such references are given, it will be impossible to make any use of the identifications so far made.

Paleontological facts also bear out these conclusions. The fauna of the Waldron shales has quite a decided relation to the Guelph fossils. It is not a typical Guelph fauna, but it has a facies approaching that of the Guelph and a fair number of species are identical. The

Clinton fauna of Ohio, however, is not at all like that of the Guelph in character, but it possesses some feautures in common with that of the Waldron beds, and a small number of identical species. This would indicate a lower horizon for the Waldron beds than for the Guelph beds, and a still lower one for the Clinton beds of Ohio. The fact that the Clinton Group of Ohio contains a number of fossils signifying a low horizon, such as *Rhinopora verrucosa*, *Phylloporina angulata*, *Leptæna prolongata*, *Strophomena patenta*, *Merstella umbonata*, *Bellerophon fiscello-striatus*, and *Discosorus conoideus*, and the fact that the Waldron beds have no such types, is additional evidence in favor of the lower horizon of the Clinton Group of Ohio. That the Clinton Group of Ohio should begin to assume the facies of the Waldron beds of Indiana, and the Waldron beds of Indiana, that of the Guelph series above, are facts which the paleontologist will recognize as being of frequent occurrence, and indicating consecutive development of life. Moreover, it is not necessary to imagine that the various strata mentioned must either be exact equivalents or entirely distinct from one another. While life ceased at one locality it was still continuous for some time at another, more or less removed, and new types gradually introduced in those localities where life has been consecutive, seem to have been introduced suddenly into the locality where life for a while had ceased, whereas it is only a case of the reintroduction of a faunna in one place after life had ceased for some time, from some other locality where life had been continuous, and where the change of the fauna had been gradual. Geological divisions are after all only convenient methods of reference, and divisions are regulated largely according to the number of breaks in the faunal development of any region. Every experienced paleontologist, however, knows that what are breaks in the development of life at one place are gradually bridged over at some other locality. This feature is in small part shown by the Clinton and Waldron beds of the West. Indeed, the Clinton of Ohio is itself a connecting bridge between the Clinton and Niagara, as shown in New York, and Dr. E. N. S. Ringueberg has found another connecting bridge at Lockport, N. Y., between the divisions themselves. Again, the Anticosti Group of Canadian geologists is a connecting bridge between the Upper and Lower Silurian series of rocks. This illustrates the fact, well known among students of ancient life, that geological divisions are not universally applicable, but that somewhere or other any dividing line is apt to fail.

GEOGRAPHICAL PALEONTOLOGY.

Reed's Hill.—East of Fairfield, a village near Osborn, is a hill that presents a fair exposure of Clinton rocks. There are about eight feet of it, worked for building stone, of an inferior quality. Neither the line of junction with the higher nor the lower strata was observed here. The stone is of a pinkish, often rose-red color, and is composed of tiny pieces of organic matter, preserving very few fossils in a condition admitting ready recognition. They are: the bases of two kinds of crinoids, *Favosites Niagarensis*, *Rhinopora verrucosa*, a species of *Fenestella*, *Orthis biforata* var. *lynx*, *Orthis fausta*, and several species of cup corals of unknown affinities.

Browns Quarry.—Two and a half miles west of New Carlisle and half a mile south of Brown's Station, on the I. B. and W. R. R., is a quarry presenting a fine exposure of the Clinton Group. The superposed strata of the Niagara Group were not noticed at this locality, although exposures are said to be not far distant. The Clinton rock is of a peculiar white color, which when ground gives it an appearance much like that of chalk. It is comparatively soft, so that the fossils contained are readily dug from the rocks, but they are also easily injured, and not being very translucent they do not admit of good microscopical sections. The ground up rock is sold for marble dust and subserves its purpose very well. A hot lime is burned from the rock which formerly was in large demand in neighboring towns, and is even now used where the management of hot limes is understood. This locality is of almost equal value with that of the Soldiers' Home Quarries, from a paleontological point of view. Brachiopods with the exception of *Rhynchonella*, are rare The trilobites are well represented and several new species are found. Of these *Ascidaspis Ortoni*, and a *Ceraurus* are the most prominent *Lichas breviceps* and *Pterinea brisa* are very common here, while in the Soldiers' Home quarries they are very rare. *Hemitrypa Ulrichi* is common, also various species of cup corals. Crinoid buttons, which form such a constant feature elsewhere are almost unknown here. Cephalopods of different genera are quite common.

Ludlow Falls.—Most of the Clinton exposures were half covered by rubbish from neighboring quarries and railroad cuts at the time of examination. The color of the stone is drab and in places dark red. A fragment of the glabella of *Illænus Daytonensis*, and a movable cheek, probably of the same species were found here. The fauna consists chiefly, however, of various corals, such as *Heliolites*, *Lyellia*, *Halysites*, *Favosites*, *Heliophyllum*, *Diphyllum* and *Streptelasma*. The superposed layers of the Dayton limestone are drab in color, and contain quite a large percentage of magnesia.

Fair Haven.—The character of the fauna is much the same as that of Ludlow Falls, with the exception of certain additions. *Striatopora* occurs in considerable abundance. Trilobites, brachiopods, and gasteropods are rare. On the other hand various bryozoans of the families *Strictoporidæ* and *Monticuloporidæ* are seen in moderate abundance.

Camp Corwin.—A mile east of Dayton lies a long range of hills, the most northern promontory of which is called Camp Corwin. On the crest of several of the hills near by several feet of Clinton rock are seen, of crinoidal structure, with few recognizable fossils. The color varies from pink to deep red. Some of the courses contain a large percentage of iron.

Todds Fork.—The exposures are three miles north of Wilmington, chiefly on the north side of the creek. Five feet of sandy rock referred to the *Medina Group* are exposed. Above this rise eighteen feet of Clinton rock, the lower courses being white limestone, quite heavily bedded, then more reddish rock of the same nature, changing into quite a heavy deposit of reddish rock above, containing much iron. The last bed is the fossiliferous one and has yielded so far: *Illænus ambiguus*, *I. Daytonensis*, *Proetus determinatus*, *Dalmanites Werthneri*, *Orthoceras Jamesi*, *O. inceptum*, *Raphistoma affinis*, *Orthis elegantula*, *Rhynchonella scobina*, *Strophomena rhomboidalis*, *Phænopora platyphylla*, *Ptilodictya expansa*, *Clathropora*, *Zaphrentis*, and *Streptelasma*.

A comparison of the faunæ of the different localities so far mentioned will show that there is considerable variation in the distribution of the different species. The most striking feature is the comparative absence of trilobita, gasteropoda, and brachiopoda, and the large development of the corals at Ludlow Falls and Fair Haven, the two more western exposures. In a line almost parallel with these are the Soldiers' Home, Fauver's, and Brown's quarries. In this line the corals, although present to a moderate degree, do not form a marked feature of the enclosed fauna. However, this is the line in which there is a considerable variety in the number of trilobites, brachiopods, and bryozoa. It is especially of value, however, as containing the best general collection of the fossils peculiar to the group in the best condition for the collector's purposes. The localities in line with Reed's Hill, Camp Corwin and the Huffman quarries are the worst localities for collectors of specimens. However, beginning at Huffman's quarry there are a few fossils at the very top of the Clinton proper, and the fauna of the Beavertown marl is also shown. At Centreville the top of the Clinton proper reaches a greater variety in the fauna, and at Todd's Fork, where there is a commingling of the two, the top strata are quite richly fossiliferous again. The question presents itself whether this distribution of the fauna can have any relation to the elevation of the Cincinnati Arch. If so, it would be a most indubitable evidence of the elevation of that arch before the beginning of the Clinton Group.

If there is so much variation in the fauna of even a quite limited district it will be well to note what forms have been found most reliable in the identification of this group, forms therefore which are characteristic and have the widest geographical range. These are: *Illænus Daytonensis*, *Illænus ambiguus*, *Dalmanites Wertherni*, *Platyostomus Niagarense* (a small and constant form) *Orthis flabella*, *Strophomena patenta*, *Phylloporina angulata*, *Clathropora frondosa*, *Ptilodictya expansa*, the various species of *Phænopora* and *Rhinopora verrucosa*. Any locality in this state or in Indiana, containing five of these species, could safely be referred to the Clinton Group as represented in Ohio.

II.

THE GEOLOGY OF LICKING COUNTY, OHIO,

PART IV. THE SUBCARBONIFEROUS AND WAVERLY GROUPS.

BY C. L. HERRICK.

In pursuance of the plan outlined in the last volume, material has been slowly accumulating, the collection and collation of literature and unraveling of perplexed synonomy being by far the most onerous task. Nearly every foot of this and much of adjacent counties has been searched by patient collectors and, in spite of the great difficulties, much progress has been made in identifying and referring to their horizons the fossils of the Waverly Group. It is hoped that even as brief a review of the fauna as can now be presented will prove helpful. Perhaps no other limited group of strata in the Palæzoic era has been the theme of more discordant discussion than this one. The problem of the Waverly deserves to rank with that of the Keweenaw and Taconic. While not claiming to settle the points at issue in this paper, it is hoped that the material made accessible by the pictorial and descriptive matter presented will at least afford every competent palæontologist with considerable material upon which to base his opinion. The methods hitherto employed in the study of the Waverly have been fatally lacking in several particulars. Generally the descriptions have been unaccompanied by figures and frequently so hasty as to make it necessary to base our opinion as to the accuracy of the indentification on the reputation of the writer. No published work has given the sequence of the fossils attributed to the Waverly, but in many cases evidence is wanting as to the fact that the stratum referred to actually belonged in the same group or formation as those with which it was collocated. The question was entirely open as to whether, for example, those species figured in the Ohio Palæontology were distributed throughout the series or were characteristic of limited zones. Many species have been referred to the Waverly, which all precedents show to be true coal-measure forms, while in a few cases Devonian species are brought into curious and unexpected relations with such species. We are quite in the dark as to whether the coal-measure forms are associated in the same actual horizon with Devonian types or whether the collocation of faunæ is more or less arbitrary or, at best, merely a theoretical result of a general survey.

The Ohio Waverly is the natural arena for the settlement of the problem as being the most accessible and the earliest known. These rocks were first confidently referred to the position of the Chemung of New York, but a more extensive comparison has shown that the Waverly is much more closely allied to the carboniferous than was first supposed. Prof. Alexander Winchell, who has given most attention to this series (which he calls Marshall) regards these rocks as the equivalent of at least a part of the strata usually referred to the Oriskany. It is our purpose to defer extended discussion of these points to the close of this series and our use of the term Waverly is to be understood as waiving the matter of terminology, though that name has priority, in Ohio at least, and its use in the restricted modern sense does not involve any ambiguity.

To illustrate what has been said of the great importance and difficulty of stratigraphical determinations we may allude to the condition of our knowledge regarding the equivalent rocks in Michigan. The serial relations in that state are, according to Prof Winchell, as follows:

Marshall Group, consisting of

1.	Napoleon sandstone	123 ft.
2.	Marshall sandstone	160 ft.
3.	Huron gritstones	15 ft.

Huron Group, consisting of

4.	Argillaceous shales and flags	500 ft
5.	Green arenaceous shales	25 ft.
6.	Black (Genessee) shale	25 ft.

Hamilton Group.

The Huron Group furnishes "all that is requisite to answer the demands of the Portage and Chemung groups. The thickness is, indeed, considerably reduced; but it must be remembered that all other New York groups traced into Michigan exhibit even a greater attenuation than this parallel would imply."

Enumerating the fossils of the Huron Group in 1870, Prof. Winchell says: "Four of the [19] foregoing species I have identified more or less doubtfully with species of the Hamilton group." "The equivalencies of these rocks are not very precisely indicated from the palæontological data. That the formation is newer than the Genessee shale is demonstrated by its observed superposition. The palæontological evidence indicates, at least, that the fauna is older than that of the Marshall group; and this is all that is necessary. If this group of rocks is proven by stratigraphical superposition to be newer than the Genesee, it belongs either to the horizon of the Portage and Chemung, or to that of the Marshall." "The Huron group, above the black shale, must correspond to the Portage and Chemung or to some portion of them."

Rominger, in 1876, writes: "The light-colored greenish, arenaceous shales on top of the black shale exposed along the shore of Big Traverse bay, may be possibly an equivalent of the Erie shales of the Ohio geologists, but no fossils have been found by which this question can be determined. The shales in the southern part ot the peninsula, which were considered by Winchell, as a part of his Huron shales occupy a higher position, and must be identified with the Waverly." "The conformity of rock material and stratification in this part of the formation, above and below the imaginary division line between the Devonian and carboniferous deposits is so perfect that no one would accept this stratum as the terminal deposit of the Devonian ocean, even if the fact were ignored that at least 500 feet of rock beds below this horizon present the faunal characters of the Cuyahoga shales of Ohio, which form the upper division of the Waverly group." The order of sequence as given by Winchell, Rominger declares entirely wrong, claiming that it was based upon a mistake of a synclinical section for a regularly descending one, so that what was regarded by the former as the foot of the section the latter affirms to be the same horizon as that at the opposite extreme. These discrepancies are here pointed out not in order to harmonize them, which would require careful scrutiny of the region in question, but as an excuse for the stress laid upon stratigraphy in this paper. Prof. Rominger again says: "Prof. Winchell considers the sandstones of Marshall as the lower terminus of the carboniferous rock series, typically distinct by its fossils from the next subjacent shaly beds, which he connects with the Devonian rocks by the character of their fauna. Such a difference in the fauna is not perceptible; the fossils of the Marshall sandstones and the subjacent shales are not only generically in full harmony, but a great number of species are common to both." This quotation may serve to justify the care with which the fossils herein noticed are limited to their horizons. It seems sufficiently obvious that central Ohio is the place where the serial relations must be made out, if anywhere, for here the stratigraphical sequence is perfectly unaltered and the horizons well marked. We present the facts collected, confidently believing that they form a firm foundation for the solution of the perplexing problem. The theoretical value of this study cannot be over-estimated. The false theory that "times of peace make no history," has too largely affected our notions of geological history. It is by tracing the succession of living forms during long periods of comparatively uniform conditions that the laws and course of development are to be discovered. Even this brief discussion demands an allusion to the views expressed by the state geologists of Ohio. In the first volume of the final report, Dr. Newberry adduces reasons for considering the Black or Huron shale as the representative of the Genesee plus part of the Portage. The remainder of the Portage and the *whole of the Chemung* is represented by the Erie shale, a group of greenish or grayish argillaceous shales limited to the northern part of the state and of small vertical extent. The difficulty of eliminating at one blow from central Ohio the great sandstone and shale series known in New York as Chemung, has, however, militated steadily against this view and most geologists have felt constrained to seek the missing formation in some larger or smaller portion of the Waverly series. It is to be noted that Prof. Newberry at that time contended that "the series of strata which begins with the mechanical sediments of the Portage has a fauna which is much more carboniferous than Devonian in character. The commencement of the epoch of the deposition of this series of mechanical sediments . . . *was in fact* the beginning of the carboniferous period."

In the second volume of the same report Dr. Newberry brings into still greater prominence the close relation, both faunal and lithological between the Waverly and the carboniferous. The general conclusions formulated are as follows: "That all its rich fauna is of a decidedly carboniferous type; second, that it includes a number of species characteristic of the lower carboniferous rocks of Kentucky, Tennessee, Illinois, Iowa, and Michigan; third, that it furnishes at nearly all of its fossiliferous localities certain species which are also common in the coal-measures above; fourth, that our collections made include no Chemung or Portage species; fifth, that it is continuous with the "vespertine" and "umbral" rocks of Pennsylvania."

The subdivisions of the Waverly are as follows:

The conglomerate (coal meas)

1.	Cuyahoga shale	150–250 ft.
2.	Berea Grit	60 ft.
3.	Bedford shale	75 ft.
4.	Cleveland shale	21–60 ft.

Erie shale (Chemung.)

It is to be noted here that what has since been called the Logan sandstone, which makes up the bulk of the exposed part of the formation south of the middle of the state is here omitted (probably as being identical with the Berea.) But doubtless nearly all the fossils, on which the judgment pronounced as to the carboniferous age of the series was founded, were actually derived from this part, i. e. our series III. The Cuyahoga or the upper part of it added to this habitus reremarkably. The careful study of the Cuyahoga will, I think, surprise geologists. If not actually a part of the coal-measure series, it has curious premonitory symptoms.

Prof. E. W. Claypole, who incidentally discusses this question in a paper read in 1884, gives the following section of the Waverly:

Conglomerate (coal meas.)

1. Logan Group (of southern Ohio.)
2. Cuyahoga shale.
3. Berea shale.
4. Berea Grit—Waverly sandstone.
5. Bedford shale.
6. Cleveland shale.

This would be adapted to our own view by transposing Nos. 1 and 2, or by intercalating No. 1 somewhere in No. 2.

Let it be observed that, in our opinion, the diversity of opinion as to the affinities of the Waverly Group is very largely due to the vain attempt to regard it as homogeneous and the failure to distinguish the Berea Grit from the sandy upper layers—Logan.

Finally Prof. Hall, in Vol. V, of the Palæontology of New York, seems to withdraw quite fully from his early view of the identity of the Waverly of Ohio with the Chemung of New York, (always comparing our Middle and Upper members—the lower being considered unfossiliferous.) He says:

"A careful examination of those species supposed to have a vertical range from the Chemung group to the Waverly group, has shown that they are allied forms but specifically distinct." He nevertheless admits that the genera are identical with those of the Chemung, only four genera of lamellibranchs being found in the Waverly not also found in the Hamilton or Chemung. The series accessible to Prof. Hall was also very incomplete.

If it should prove that many Chemung forms persisted in Ohio long after the shallowing waters of New York were unfitted for them and that forms of carboniferous habit were gradually introduced it would only furnish another to the long list of similar instances standing to the credit of evolution.

For an extended and very valuable discussion of the age of these rocks, see Winchell's papers in Proc. Philos. Soc. Vols. XI and XII, 1870.

That the series of freestones and shales with occasional interspersed bands of conglomerate which occupies a belt of 250–500 feet below the coal measures is really homogeneous may have been doubted, but it is left for the present occasion to point out the nature of the variations in the fauna. The stratigraphy of the Waverly as seen in central Ohio may now be confidently regarded as correctly determined in at least its general contours. The interest attaching to the Waverly group as affording a transition from Devonian to carboniferous faunæ under peculiar conditions will naturally be greatly enhanced if within its own limits transitional forms or facies can be discovered. To gather facts instructive upon this point it is necessary, first of all, to identify continuous and unmistakable horizons. To this end we first directed attention, and found such reference lines in two narrow bands of conglomerate separated by an interval of from 38 to 50 feet, which includes the quarry rock or freestone employed in this county.

Though the conglomerates may disappear or vary, the fauna of the subjacent shales afford conclusive criteria for ascertaining at least their approximate position. With these two lines of reference once established, and leveled east and west through our district, the study of higher and lower horizons became more fruitful.

Before discussing the work in this field it becomes necessary to recall some points already stated in the first paper. It will be remembered that our attention was given solely to a thin band of shale lying about 160 feet above the bottom of the coal-measures at Flint Ridge. In the same report a band of limestone is referred to as occupying a place about 100 feet above the Maxville limestone, in Muskingum county and conjecturally referred to the position of the lowest coal seam east of Newark, at Bald Hill. This limestone has been further examined, and although it has not yet been found possible to satisfactorily demonstrate our position, the palæontological evidence is not inconsistent with that theory. West of Fultonham this thin band is well exposed and lies about 120 feet below the coal mines of that region. If these coal mines are on the same horizon as that at Flint Ridge, the relation is the same as at that place, except that a few feet are interpolated (as would be expected) above and below. The limestone in question is sometimes dark and shaly, at others is dense and crystalline. Its fauna is quite large and the following species have been identified.

1. *Productus cora*, rare, though common as at Flint Ridge.
2. *Productus semireticulatus*, common.
3. *Productus longispinus*, not common.
4. *Chonetes mesoloba*, rare.
5. *Athyris subtilita*, common.
6. *Spirifer cameratus*, (= S. striatus.)
7. *Allorisma subcuneata*.
8. *Naticopsis nodosa*.
9. *Naticopsis nana ?*
10. *Macrocheilus ponderosus ?*
11. *Macrocheilus planus ?*
12. *Macrocheilus paludinæformis*, small form.
13. *Macrocheilus fusiformis ?*
14. *Bellerophon nodocarinatus*, fine large specimens.
14. *Bellerophon* sp.

The fifteen species discriminated are beyond doubt coal-measure forms and the chief difference between the assemblage and that at

Flint Ridge is in the relative abundance of the species. Naticopsis nodosa has not been recognized from the Flint Ridge shales and Productus semireticulatus is abundant in the Waverly, but rare in the Flint Ridge shales. It is possible, but not probable, that the two horizons are identical. The sandstone and shales underlying this band are unfossiliferous and the next link in the series connecting the coal-measures and the Waverly is found in the so-called Maxville or Chester limestone. A considerable fauna will yet be restored to us by a sufficiently prolonged search in the limestones and shales of this series in Ohio, which is nearly 25 feet thick in the vicinity of Fultonham. Eleven species have been described from this horizon by Whitfield. The characteristic species which are everywhere abundant are *Productus parvus*, which, however, is often much larger than the type and approaches P. semireticulatus in some characters, *Spirifer glaber*, *Athyris subtilita*, *Euomphalus planodorsatus* and *Bellerophon* sp. *Pleurotomaria chesterensis?* *Holopea newtonensis?* *Nautilus spectabilus*, *Ctenodonta?* sp. *Allorisma andrewsi*. (Plate XIII, Fig. 12) and *Spirifer increbescens*, H. With regard to the last mentioned species it may be here noted that no difficulty exists in tracing this species to its successor in the coal-measures (S. opimus) and to its probable progenitor in the St. Louis group (S. Keokuk var. Hall), this in turn to the Keokuk group. There are many hints of this sort which will occur to the attentive student of these successive faunæ. A cup coral, Lophophyllum sp? (See Plate XIII, Fig. 17), also occurs rarely.

In this connection may be described

Nautilus (?) bisulcatus, sp. n.

(Plate XI, Fig. 16.)

Shell of moderate size, very compressed rotate, volutions not embracing, (two to three?) transverse diameter of outer volution less than one-half the dorso-ventral diameter, transverse diameter greatest one-third from the ventral side; upper and lower surfaces marked dorsally by a carina within which is a broad, shallow grove, followed by a second ridge about one-third from the dorsal margin, succeeded by a groove shallower than the first, which is followed by a gently convex portion extending to one-fifth from the ventral margin, where is a slight carina, beyond which the surface inclines to meet the similar plane of the opposite side at an acute angle, the resulting surface being slightly concave.

Our specimens are fragments which do not furnish material for careful description. The symmetrical relation of the two sides indicates a cephalopod in spite of the apparent absence of septa. The siphuncle seems to be central. The greatest diameter was not less than 75 mm; dorso-ventral diameter of volution near end, 15 mm; lateral diameter of volution, 6 mm; the width of the plane dorsal margin is 3 mm *N. pauper*, Whitfield may prove identical with our form, but it would not be suspected except from incidental similarities and the fact that our form is derived from the same horizon at Fultonham.

West of Fultonham, two or three miles, are exposures which permit the reconstruction of the following section:

Coal measure sandstone (exposed)	10 ft.
Bituminous shale	3½ ft.
Limestone	18 in.
Shale (many fossils)	2½ ft.
Sandy layer	5-6 ft.
Firm limestone	6-10 ft.
Shale	3-6 ft.
Reddish and grey silicious shale and free-stone—Waverly (exposed)	10 ft.

The section not being continuous may not be very accurate, but expresses the approximate relations. No inconformity could be detected between the shales forming here the base of the coal-measures and the reddish layers, which are undoubtedly Waverly and contain *Chonetes illinoisensis* and other characteristic fossils.

The Waverly layers for some distance below the coal-measures are, except in a band about 4 feet from the top, apparently unfossiliferous. About two and one half miles east of Rushville is exposed about 20 feet of Waverly, which lies about 70 feet below the top of the Chester (Maxville) and hence, if that series has there its maximum development, some 50–60 feet below its base. This exposure is interesting on account of the presence in it of a Trilobite (*Phillipsia meramecensis*) not found in the lower beds of the Waverly and having a decided carboniferous habitus. At Rusville the following section is exposed:

Shale, with Productus semireticulatus and Spirifer striatiformis	100 ft. above congl. II.
Shales and thin bands of freestone	30 ft.
(Pleurotomaria, etc.)	
Nodules of lime (fossiliferous)	65 ft. above congl. II.
Shales.	
Freestone, 40 feet above congl. II. Nautilus sp., Hemipronites, Productus arcuatus, etc.	about 10 ft.
Shales	about 30 ft.
Conglomerate and sandy freestone	5 ft.

"Conglomerate II" forms the basal, 18 inches or so, and here is not very coarse.

Shales, with Allorisma winchelli, Prothyris meeki, Sanguinolites obliquus, Grammysia ventricosa, and Pholadella newberryi.

This last is the lowest horizon seen in this part of the state and corresponds to the shales overlying the freestone in Licking county. The fauna found at the highest horizon of Waverly in Licking county, is here encountered here near the top and the various species can be allotted to their position in the series with unexpected ease and certainty.

The little excursion thus made into Muskingum and Perry counties enables us to complete the series in its normal condition. However, the moment we turn our attention to our allotted task in Licking county, we discover that the series is imperfect at one point. While conformity between the upper Waveriy and lower Chester does not exclude the idea of a considerable interval of time between the fossiliferous bands of the two groups, it is apparent that in Licking county the Chester interval is unrepresented and that much of the upper Waverly is generally absent, so that the white sandstone or conglomerate of the coal-measures lies unconformably on one or other of the Waverly beds and the upper surface of the Waverly itself has obviously suffered erosion. The amount of the erosion varied in different places and where greatest is covered by coarse quartz pebbles of granitic origin mingled with coal measure trees of large size. The suggestion of extensive erosion been heretofore made, but absolute proof has been wanting. It is has our privilege to complete the evidence and to point out in general the amount of loss thus incurred. It has been quite generally supposed that an elevation of the coast at the close of the Waverly period caused the recession of the water, and that the period occupied at the west by the deposition of some 550 feet of sediments was not a time of rock formation in central Ohio. The results of close study of the lowest coal-measure conglomerate has unexpectedly indicated the contrary. While engaged in collecting samples of the quartz pebbles forming the bulk of this conglomerate eight miles northeast of Newark, a large number of fragments of limestone were also broken out.* These are angular and, though very badly decomposed, show that they could not have been derived from a distance, as the quartz must have been in order to free itself so fully of the softer, including country rock, and acquire its rounded form, and, moreover, they contained a few fossils which can only be referred to the age of the Chester or St. Louis Group. These conglomerates are full of the impressions of Lepidodendrids and Calamites and seem to have been torn from their places by torrents which carried from the mountains to the north their freight of coarser and finer material, much of it being of a metamorphic and igneous nature. The Chester limestone must at that time have been more or less firmly consolidated, perhaps in the form of clods of limy clay, and has preserved identifiable remains to tell the story. Thus the same coarse conglomerate tells us that a mighty river flowed into the coal-measure ocean from a region to the north, exposing igneous and metamorphic (partly granitic) rock, that it flowed through a region covered by deposits of St. Louis or Chester age, thus showing that a large series supposed to be absent in this part of the state was simply obliterated by erosion. Such a chain of argument indicates what possibilities are open to a more careful study of limited areas. The fossils referred to are figured beyond, in connection with those of the Chester further south.

We now pass to the Waverly proper. This may be divided into three well-marked groups which present us with a carboniferous, a Waverly, and a Devonian facies respectively. The lower division ought probably to be referred uncompromisingly to the Devonian, the second, less obviously Devonian, still contains a fair proportion of Chemung fossils, while the upper series can be unhesitatingly called sub-carboniferous. These zones are marked off, as already hinted, by two bands of conglomerate, which include between them the middle member or Waverly proper.

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*The Ohio geologists have observed the same fact in other parts of the state, but a different interpretation has been offered.

The upper Waverly, with its 100–150 feet, has been rather less studied than either of the other divisions. Near the top it is characterized by *Productus semireticulatus*, *Spirifer stratiformis*, *Phillipsia merameccensis*, *Nautilus* sp, *Crenipecten*, sp. n. *Hemipronites* is also very abundant.

The upper conglomerate, or congl. II. is itself often fossiliferous with the species characteristic of the shale below and especially *Spirfer winchelli.* *Allorisma winchelli*, *A. ventricosa*, *Sanguinolites obliquus*, *Prothyrus meeki*, *Edmondia*, etc., are the determinative forms for the shale. The free-stone which lies below this shale is full of fossils. *Spirifer carteri*, *Crenipecten winchelli*, *Phillipsia shumardi*, *Rhynchonella cooperi* and *R. contracta* are characteristic of this zone. After an interval of shale, sometimes with *Allorisma winchelli*, but generally barren, we reach congl. II, which varies from a narrow belt of sandy freestone to 10 feet of coarse sand and conglomerate. A few feet below this is one of the most characteristic layers of the whole formation, abounding in *Palæoneilo concentrica*, and *P. attenuata*, *Sanguinolites unioniformis*, *Streblopteria media*, *Bellerophon lineatus*, *B. galericulatus*, etc., etc. The same fauna may be found for 30 feet below, but 40-50 feet below is a zone with quite a different habitus, containing *Rynchonella sappho*, *Leiopteria ortoni*, *Crenipecten tumidus*.

Near the same horizon, probably below it, but exposed further west and not yet certainly located vertically, is a zone with *Spirifer marionensis*, which species is also abundant in limestone nodules some 15–20 feet lower along with a peculiar fauna of considerable individuality, at Moot's run.

Through the kindness of Mr. E. S. Clarke, a system of levels was run from Granville to exposures eastward from Newark, correcting the barometric work of last year. The conglomerate I. being the most available base line, the levels refer to the top of this stratum, which is exposed along "the avenue" leading to the buildings of Denison University. Along a line bearing S. 68° E., for 3.85 miles, this conglomerate dips 79.35 feet, from this point to the south Newark quarry, a distance of 4.44 miles S. 79° E. the dip is 48.74 ft. A portion of the difference in inclination is due to the increased thickness of the conglomerate to the eastward, but the influence of the Clay Lick arch is also beginning to be felt. In our last report the mistake was made of paralellizing the conglomerate I. at the Dug-way, (or the first of the above mentioned stations) with the second conglomerate at the south Newark quarry, thus making the combined Waverly section too small by 39 feet. In like manner a level (barometric) between Granville and Cat run, a distance nearly due north of 5½ miles, reveals a dip to the south along congl. I. of 79 feet, or over 14 feet per mile. The section at this place is

4.	Freestone and part of shale below congl. I.	35 ft.
3.	Shales and freestone	29 ft.
2.	Congl. I, coarse pebbles. loose	16 in,
1.	Shales with Palæoneilo attenuata	14 ft.

The relations are almost precisely as at the Dug-way. Passing southwest from Granville, a distance of three miles, at Cheney's run, we find, at the bottom, a fossiliferous band marking the horizon 40 ft. below conglomerate I. This is about 30 feet higher than at Granville, a dip of only 10 feet per mile. Now passing due west to a point 4½ miles west of Granville, the bridge over Moot's run is reached. At this place a fossiliferous layer of shale is found 36 feet higher than the last mentioned, which would permit this horizon to be identified with the 40 ft. layer above mentioned assuming a dip of 12 feet per mile to the east. There are, however, at this place indications of a local increase in dip, and this layer contains *Spirifer marionensis* and few fossils identified in the 40 ft. layer farther east, while 20 feet above are layers with the lithological character of that horizon (unfortunately unfossiliferous.) At the foot of this exposure, 20 feet below the *Sp. marionensis* layer. are found specimens of *Chonetes logani* and *Rhynchonella sappho*. Passing one mile west, a very interesting bed of shale with limestone nodules is exposed. This bed is very fossiliferous and is the lowest richly fossiliferous bed known in the Waverly. This is thirty feet above the Spirifer marionensis layer and, allowing a dip of 15 feet to the mile, would still lie at least 15 feet above that horizon stratigraphically. It probably is upon nearly the same horizon. Continuing west twelve miles to Rocky fork, a series of gritty flags and shales is reached about 15 feet higher than at the *Sp. marionensis* layer at Moot's run, by barometer; thus, allowing a dip of 14 feet per mile, we reach a horizon about 170 feet below that layer. At a point three or four miles farther west and south, not far from Gahanna, these gritty layers are quarried and are interspersed with layers of bituminous shale like the Ohio black shale. A point quite near the foot of the Waverly is here reached 120 feet below the last mentioned zone. As the southern element in the dip is here quite appreciable, it would be an ample allowance to estimate this horizon at 150 feet below the last named, or 320 feet below the lowest fossiliferous zone of the Waverly. Near Summit on the Baltimore and Ohio R. R., we find the following section:

6.	Shaly freestone	10-15 ft.
5.	Blue shale	4 ft.
4.	Grey calcarous sandstones	12 in.
3.	Blue shale	10 ft.
2.	Unexposed	70 ft.
1.	Black "Ohio" shale	30 ft.

The entire unfossiliferous part of the Waverly may therefore be estimated at less than 350 feet, and the Waverly series in Licking Co. at less than 570 feet. Probably 550 feet would about cover it.

A generalized section of the Waverly in Licking Co. is as follows:

	Carboniferous conglomerate	
14.	Upper Waverly, shales and flags with few fossils. Phillipsia meramacensis, Productus arcuatus, Prod. semireticulatus, Aviculopecten sp., etc	about 100 ft.
	Best exposed at Bald Hill and 1 mile north of Newark.	
13.	Shales, soft, with few small fossils	4 ft
12.	Conglomerate II. Spirifer Winchelli	18 in.
11.	Shale, "Allorisma layer." Spirophyton	7 ft.
10.	Freestone (Berea? many fossils	30 ft.
9.	Shales, barren	15 ft.
8.	Conglomerate I	1–4 ft.
7.	Shale "Lamellibranch layer"	4 ft.
6.	Shales, same fauna, less prolific	26 ft.
	Flags	12 in.
5.	Shales, barren	10 ft.
4.	Flags, with Rhynchonella sappho, Leiopteria ortoni, Strebloteria media, etc	18 in.
3.	Shales, barren	20 ft.
2.	Shales, with Spirifer marionensis	18 in.
1.	Shales, barren, Flags and black bituminous shale	about 350 ft.
	Black shale.	

All below congl. I. is spoken of as division I, Ia being that portion of this division over 40 feet below this zone, Ib the upper 40 feet. Division II includes all between congl. I and II, and division III, the remainder.

In our study all collections made before the discrimination of these various horizons were abandoned and the whole recollected, labeling each fossil with its relative position with reference to the base line. The typical exposure of the county is that formed by the erosion of Raccoon creek, near what is known as the "Dug-way," between Granville and Newark. It is supplemented by that one mile south of Newark and one mile north of the same place. Exposures six miles further east corroborate the observed sequence. The lower layers can be best studied at Moot's run, four miles west of Granville.

The most significant determinative fossils are Allorisma winchelli, of the shale below congl. II; Spirifer winchelli, of congl. II; Spirifer cuspidatus, of division II; Palæoneilo attenuata, of shales below congl. I; Leiopteria ortoni of the 40 ft. layer below; Spirifer marionensis, of still lower horizons. The discussion of the stratigraphical relations of the various species is omitted and the reader is referred to the distributional table at the close.

Outside of Licking county considerable work has been done which is here only so far employed as to verify the observed relations. It is reserved for another occasion when a wider range of comparison may be admissible.

LIST OF FOSSILS FROM LICKING COUNTY, OHIO.

This list has been compiled under almost disheartening difficulties and is merely a, preliminary contribution to the fauna of the group. Certain subkingdoms have not been studied at all and as the plates were engraved prior to the elaboration of some families typical forms have not always been figured. The collection of additional specimens may affect determinations here made, but it is not believed that further study will materially alter the relative value of the chronological evidence. I wish here to express obligations to Prof. Alexander Winchell, the renowned geologist of Michigan, for indispensible assistance. A small suite of specimens and part of the plates were placed in his hands, which he kindly examined and reported upon, thus preventing serious mistakes. However, it is but just to say that the nature of the material sent was such that, even where his views are quoted, it would be unfair to implicate him in the mistakes contained in this paper for which the writer assumes full responsility, at the same time acknowledging himself indebted very largely for whatever value the paper may have to the disinterested generosity of his distinguished friend. Equally indispensible has been the work of friendlv collectors, Mr. W. F. Cooper having assisted most largely, while Messrs. C. J. Herrick, Ira Crawford, E. S. Clarke, J. L. Deming, and many other students and friends have similarly assisted.

The tabular review is intended to exhibit at a glance the general stratigraphical conditions as well as certain comparisons bearing on the age of the group. It will be constantly remembered that only a part of the species collected are described in this number.

I. signifies all below conglomerate I, as seen at the foot of the south Newark quarries; II. is that section including the freestone at Newark and ending with conglomerate II, 50 feet above the base of the quarries at Newark; III. is the remainder of the series including shales and flags to the base of the Chester or coal-measure conglomerate as the case may be.

Phillipsia meramecensis, Shumard.

(Plate XI, Fig. 3.)

A single pigidium from near the top of the Waverly east of Rushville.

Pigidium considerably wider than long, parabolic in outline, with a very narrow border; axial lobe broad and high, fully ⅓ as wide as the pigidium proximally, composed of thirteen narrow, unsculptured segments, prominently truncate behind, separated from the pleuræ by a not very deeply impressed sulcus, but rising above them almost at once; pleuræ rather convex, eight segments being evident, which are low and flat, with a slight groove on the top of the first and second near the posterior edge; the narrow border of uniform width and abruptly deflected. Length 8 mm; width 11 mm; width of axial lobe 7 mm.

The figures given by Shumard do not show the characters emphasised in his description, which agrees quite fully with our specimen. The species was originaly found in the Archimedes limestone at Fenton, St. Louis Co., Missouri, a horizon, apparently the equivalent of the one here noted.

Phillipsia shumardi, Herrick.

(Plate II, Fig. 22.)

Proetus missouriensis, SHUMARD. Geol. Missouri.

Abundant in the freestone of middle Waverly. See Bul. Den. Univ. Vol. II, Part I, page 69.

Phillipsia praecursor, sp. n.

(Plate XII, Fig. 1.)

Closely related with P. shumardi, Her.

Head shield parabolic in outline, axial portion very high, rapidly curved, highest portion near the centre of the glabella. Glabella nearly twice as long as wide, anteriorly forming a high, rounded, finely striate ridge, separated from the axial elevated portion by a deep but narrow sulcus; postero-lateral lobes small, oblique, well defined by the arched grooves which reach the cervical groove or nearly so, and separated from each other by an interval equal to their own width; there is but a single pair of secondary on lateral lobes with a pretty well defined sulcus lying well back of the centre; palbebral lobes large, quadrate; cervical suture deep and wide, cervical segment rather large. The cheeks are bordered by a triangularly elevated margin and a rather deep groove and project backward into short, acute spines. None of our specimens show the fixed cheeks and the figure of the head is imperfect in this respect, but bears a strong resemblance to P. gemmulifera. Pigidium nearly semicular, moderately elevated, about 1½ times as wide as long, the axial portion is high, tumidly conical, and obtuse, marginal sulci rather deep; axis composed of nine (ten) segments separated by deep grooves, pleural portions rather regularly convex, with about seven apparent ribs which are elevated and pustulose dorsally and bifurcate near the margin; margin convex, separated by a shallow groove. All of the annuli as well as the median parts of the gebella, are covered with well defined pustules. Length of glabella 14 mm; width 7 mm. or more; length of pigidium 11 mm; width 17 mm.

This form is obviously very nearly allied to P. elliptica from the

Kinderhook of Ill. and P. swallovi, from the Chouteau limestone of Missouri, but seems quite distinct.

From nodules in shale at Moot's run, also in the shales containing the same.

Pleurodictyum Problematicum, Goldf.

(Plate VIII, Fig. 15.)

"Corallum depressed, sub-hemispherical, or semilenticular; the under side concave and provided with an epitheca, the upper convex. Corallites somewhat irregular in size and form, more or less angular, often hexagonal, short, increasing rapidly in size and so distinctly radiating from the middle upwards and outwards, that those of the lower series lie nearly or quite parallel to the concave base, and even decline as they extend out from near the middle to the periphery—those rising from near the middle shorter than the others; connecting pores as indicated by their casts, rather numerous, and apparently irregularly arranged, sometimes passing through the corners as well as the sides of the [illegible] between the corallites."

A [illegible] of this interesting compound coral were found [illegible] in the upper layers of freestone near congl. [illegible] first noticed by Meek and Worthen. The [illegible] referred to the Onondaga section of the [illegible] by the Illinois geologists seems to belong at a higher horizon than first supposed; at least the presence of the same form in the Waverly group, pretty well up in the series, lends probability to this [illegible].

Orbiculoidea sp.?

(Plate VIII, Fig. 14.)

A large species of Discina-like appearance is common in the shales of the middle Waverly and has been usually referred to D. newberryi, Meek. As only the dorsal valve is known and this is larger than the type, we prefer to defer identification. There is a ridge rather than a slit, as in Discina and the shell is usually distorted.

Crania hamiltoniae, H. (?)

(Plate XII, Fig. 10.)

This little species is found adhering to mollusks and brachiopod shells and is largely modified by the ornamentation of its host. Our specimen agrees as fully as might be expected with the smaller varieties of the species quoted.

Broadly oval or sub-circular; dorsal valve sub-conical; apex subcentral or excentric, pointed, surface marked by very fine (scarcely lamellose) striæ. Lower valve not seen. Concretionary layers at Moot's run—lowest fossiliferous horizon.

This species, whether specifically identical with C. hamiltoniæ or not, has a decided Devonian aspect.

Productus Nebrascensis, (?)

(Plates I, Fig. 24; III, 23(?) 23a.)

Specimens having the characters of this species are widely distributed. Though never attaining a very large size there is a considerable range of variation in this respect as well as in outline and form. The rather regular and prominent pustules are sufficiently characteristic. The species is known from the horizon of congl. I, to the top, but may descend lower.

Productus semireticulatus.

(Plates I, Fig. 26; III, 24; VII, Fig. 11; X, 6, 6a.)

This widely distributed species is especially characteristic of the uppermost Waverly, as found at the tank north of Newark and in the freestone. The species attains a large size and may be recognized by the great prominence of the ventral valve near the strongly incurved beak.

Productus arcuatus, Hall.

(Plate III, Fig. 18.)

Prof. Hall's description runs as follows:

"Ventral valve much elevated, longer than wide, very gibbous, extremely arcuate, the beak recurved upon itself so that the hinge line is nearly opposite the centre of the back of the shell; hinge line shorter than the width of the shell; cardinal extremities produced into small angular ears. Surface marked by strong radiating costæ, which bifurcate upon the umbo and below, and sometimes coalesce toward the base of the shell; entire surface covered by fine undulating concentric striæ, and, in the upper part, a few strong wrinkles, which are conspicuous on the ears and umbo. A few marks of the bases of spines are noticed, but they appear to have been irregularly distributed."

This species is P. semireticulatus in miniature. Our specimens differ from Hall's figures chiefly in the greater irregularity of the striæ, in this respect, however, agreeing with his description.

Length 17 mm; width about 15 mm; hinge 14 mm. Near congl. II, Granville and Newark.

Productus flemingi, var. burlingtonensis. H.

(Plate III, Fig. 20 [and 22?])

A few specimens, apparently from the upper division of the Waverly, resemble very closely this species. The occurrence of a Burlington species in this horizon is certainly suggestive.

Productus (Productella) shumardianus, H.

Plate VII, Fig. 18; Plate VI, Fig 16?)

(= Productus subaculeatus, Murch.)

Productus subaculeatus, has been identified by Hall, from the Corniferous He says:

"I have been unable to identify it with any species in the Hamilton and Chemung groups of New York, though the resembling those which I have placed under P. shumardiana. A larger collection of specimens may possibly show a passage from one to the other."

Productus shumardianus is doubtless identical with *P. spinulicostus*, H., *P. concentricus*, H: and *P. pyxidata*, H., while *P. lachrymosa* is perhaps less closely allied, though a member of the same series.

Productus dolorosus, Win., is apparently a synonym for *P. truncatus*, H., and has not yet been certainly identified within our limits.

Typical ventral valves of P. shumardianus are frequent in the sandy parts of conglomerate I, though never found much above this horizon. A dorsal valve apparently of this species was found in the nodules at the foot of the exposure at Moot's run, at least 50 feet below the horizon of conglomerate I. I quote Hall's description.

"Shell concavo-convex, sub-hemispherical, wider than long; hinge-line nearly or quite equalling and sometimes greater than the shell below. Ventral valve very convex, gibbous in the middle and on the umbo, which is abruptly narrowed toward the beak, and the apex curved over the hinge-line; the sides abruptly depressed toward the cardinal extremities, which are flattened and more or less auriculate. In one specimen observed, the apex is minutely truncate, and there is a barely perceptible line at the junction of the two valves, which indicate an area. Dorsal valve concave, often corresponding essentially with the ventral valve, but sometimes nearly flat in the upper and central portions and abruptly deflected toward the margin. Surface of the ventral valve marked by intermittent radiating ridges, gradually rising from the surface and terminating below in elongate spines; while upon the upper part of the shell, about the umbo, there are scarcely perceptible elevations of the surface above the base of the spines. * * * The entire surface is marked by close concentric undulating striæ."

The cardinal process of the dorsal valve is bifurcate. Figs. 6, 6a, 6b and 11, of Plate XII, illustrate various conditions of this species, Fig. 6 especially resembling P. spinulicostatus.

[*Productus concentricus*, H.]

(Plate VI, Fig. 16.)

(= P. shumardiana, H. ?)

The identification of this dorsal valve was suggested by Prof. A. Winchell, but it is made with some hesitation, as the specimen was found associated with P. shumardianus as above indicated. In markings, both concentric and pustulose, the valve agrees better with that species from which it seems to differ somewhat in form. Nodules, foot of exposure at Moot's run.

Productus (Productella) lachrymosus. var. stigmarius, H.

(Plate III, Fig. 28.)

(Cf. P. curtirostra, Win.)

A few specimens, mostly poorly preserved, from the nodules at Moot's run, represent this or a closely allied species. The specimen figured shows only the cast of the dorsal valve. The fine, wavy concentric striæ and interrupted radiating ridges, and slight mesial sinus can all be duplicated in New York specimens.

A large ventral valve measures 40 mm. in width, 30 mm. in height, and about 18 mm. in convexity of valve. There is a faint but obvious sinus and the surface is marked by nearly obsolete coarse ribs, as well as the fine, irregular concentric striæ. Prof. Hall suspected that this large form would prove distinct from P. lachrymosus, in which we concur.

Productus (Productella) speciosus, H. ?)

Specimens more nearly agreeing with the Chemung species than those with which it is associated, have been secured. These specimens are characterized by numerous, rather regularly arranged, small pustules covering the entire surface. Moot's run, calcareous nodules.

Productus gracilis, Win.

(Plate VII, Fig. 20.) No. 1347.

The original description reads as follows:

"Shell small, aperture of the ventral valve forming a little more than a simicircle. Ventral valve moderately inflated for a Productus, with flattened, smooth, triangular auriculations; hinge-line equal to greatest width of shell; mesial sinus wanting or barely perceptible; external surface marked by fine, rigid, sharp, once dichotomizing radial striæ, numbering about 40. No indications of spines have been detected. Length of hinge-line .29 in., length from beak to anterior margin, .21."

Our form is nearly as large again and has the hinge line shorter than the length of the valve, nevertheless we dislike to attempt to distinguish it from a species confessedly founded on a single imperfect ventral valve. Our specimen, however, has no spines and a compound dischotomy of the striæ. Sandy layers of congl. I, "Dugway," near Granville.

Chonetes logani, Nor. and Pratt.

Plate VII, Fig. 22; Plate III, Fig. 12?)

In Fig. 22, Plate VII, the radiating costæ are not distinct enough, while the specimen figured on Plate III may prove to be C. multicosta, Win. C. logani seems to be distributed throughout the series up to congl. II, at least.

The confusion introduced into this genus by identifying this species with C. illinoisensis, has been corrected by Prof. Winchell.

Chonetes illinoisensis, Worthen.

(Plate III, Fig. 21.)

Rather large for the genus, transversely semioval; moderately convex ventrally; length between two-thirds and three-fourths the width; hinge line nearly equal to greatest width, with five or six small oblique spines on either side of the inconspicuous beak; ears somewhat flattened; nearly rectangular; front margin a broad curve; surface of ventral valve rather evenly convex, highest near the middle, casts showing a strong mesial septum; dorsal valve gently concave, with distinct cardinal teet. Surface ornamented with about 100 bifurcating, thread-like striæ. Length 7 mm; width 11 mm. Our specimens rarely attain the size of the western ones, though often much larger than the above measurements.

Found in the sandy rock above congl. I; also forty feet or more below this horizon at Moot's run. The spines of this species are much more slender and curved than in S. scitula.

Chonetes scitula. Hall.

(Plate I, Fig. 4.) No. 1397.

Shell small, semi-oval, hinge-line about equal to greatest width, tumid along the medial line. Ventral valve, moderately convex along a line from the beak to the front margin, about one-third the entire width, thus elevated near the front, lateral margins depressed; beak slightly prominent, hinge-line somewhat angled, armed at either extremity with at least two spines. Surface marked by fine but rather prominent, distant striæ which do not bifurcate, sometimes somewhat alternate. Width about 8 mm, height 5 mm. Dorsal valve nearly plane. Near the base of the series at Moot's run, probably 50-60 feet below congl. I.

Our specimens agree even to details of hinge structure with those of New York. The spines are strong and oblique.

Another form found near congl. II, or about 80 feet above the present species, resembles this in form, but has more numerous bifurcating striæ. This we compared with *C. setigera*, H., but though closely agreeing otherwise, our species has oblique spines on the hinge.

Chonetes tumidus, sp. n.

(Plate II, Fig. 21.)

Shell of medium size, closely resembling C. acutiradiata of the Corniferous group of New York.

Ventral valve very convex (as much so as C. hemispherica of the Upper Helderberg), hinge extended, with mucronate extremities, straight, apparently with few oblique spines; body of the shell nearly semi-circular, forming nearly a segment of a sphere, being suddenly depressed to the flat ears, which are acutely triangular. Umbo somewhat prominent. Surface marked by numerous (50), regular, nearly continuous, rounded striæ, which rarely bifurcate. Exfoliated specimens show numerous oval pores between the striæ. Dorsal valve not known. This very pretty species is found in the irregular calcareous nodules at base of the section at Moot's run and adds a significant Devonian color to the facies. The resemblance to C. hemispherica is close, but the outline is as in C. acutiradiata, H.

Width 12 mm, height 7 mm.

Chonetes pulchella, Win.

(Plate III, Fig. 14.)

"Shell small, semi-circular; hinge almost equalling the greatest width, rectangular at the extremeties, furnished with two or three stout hollow spines on each side of the beak, one projecting from the hinge extremity, and diverging at an angle of about 22° with the hinge-line —the second half way to the beak and diverging at an angle of 45°, each of these spines having a length equal to half the hinge line. Ventral valve, exclusive of the flattened hinge angles, spherically convex; internal median ridge extending to the middle of the valve. Surface with about 54 feeble, rounded ribs, often nearly obsolete on the hinge angles; these are crossed by numerous microscopic, concentric striæ; the grooves beneath the ribs are acute and bear a few spinous projections near the shell margin. Dorsal valve nearly flat, generally a little concave near the margin, marked, like its fellow, with radiating lines, and often a few concentric folds. Area very narrow, equally excavated in both valves."

Our specimens are 7 mm. wide and about 5 mm. long. Kindly identified by Prof. Winchell. Specimens believed to have come from the free-stone of middle Waverly, Granville, O.

Hemipronites crenistria, Phil.

(Plates V, Fig. 14; III, 24; Plate VI, Fig. 8; Plate IX, Fig. 21.)

The great variability of the American members of Hemipronites makes any attempt to restrict the limits of species very difficult—for us, impossible. The figures indicate the extremes of the series abundant in the middle Waverly.

This widely distributed species occurs in all the strata containing numerous fossils. The largest specimens seen come from the same horizon as Spirifer marionensis, probably 60 feet below congl. I, though these are less than half the size of the largest figured by Davidson. (Sup. plate XXXVI.) These are very transverse and the striæ are very fine and frequently irregular. The ventral valve is only moderately convex. (Dorsal valve 58 mm. wide, 30 mm. high) about 13 striæ in 5 mm. (near the margin.) In the shale below congl. I, specimens much less transverse and with distinctly alternate striæ occur. In the free-stone this form occurs with *var. cylindrica* (= var. robusta, Hall), which latter, or a still more Orthis-like variety, occurs in congl. II.

Orthis Vanuxemi, Hall, var. pulchellus, var. n.

(Plate V, Fig. 9.) No. 1396.

This beautiful little Orthis occurs in large numbers in a zone near the top or above the top of the quarry rock in Granville, and seems to pass into forms resembling those generally identified with O. michelina. Without discussing the probable relationships of the two forms we may simply notice the close resemblance of our specimens to those described by Prof. Hall, from "calcareous shales of the age of the Hamilton group" in several localities in Illinois, Missouri, Iowa, and New York.

Shell nearly circular or sub-quadrate in outline, depressed, ventral valve generally longer than wide, most convex one-fifth from the beak, flattened, but not sinuous below. Hinge line short; beak rather prominent, protruding, acute; ears depressed, rounded. Surface covered with numerous small, tubular striæ which increase by bifurcation or more rarely implantation, sometimes by division into three, striæ with perforations or oval punctures; surface also marked by concentric striæ and more distant imbricating lines especially near the front margins; about three striæ in the space of one millimeter. Foramen with cardinal process; interior of valve with large vascular impression, and mesial process. Dorsal valve nearly circular, convexity above the middle, cast with a broad mesial sulcus from the beak to near the middle. Length of ventral valve 15 mm; width 15 mm.

Orthis michelina, var. burlingtonensis, H., is hardly at all different. In it the perforations upon the striæ are represented as elongate rather than circular, in which point our specimens agree.

More typical specimens of O. michelina also occur in the freestone.

Rhynconella contracta, H.

(Plate X, Fig. 9.)

We are quite unable to distinguish any differences between a small species with very acute plicæ and that described by Prof. Hall, from the Chemung. Prof. Hall himself made the same identification in 1867, and as the name was applied in 1843, it ranks any other name in vogue for the same shell. The range of individual variation is as great as in that quoted. The species is rare in the free stone of middle Waverly.

In a genus as conservative as this one a greater vertical range of species is to be expected than in many other groups.

Rhynchonella subcuneata, H.?

(Plate VII, Fig. 23.)

A small species from just above conglomerate I. has nearly the form of the species quoted. The sandy matrix makes a careful study impossible. Our specimen is smaller and less broad than Hall's types, but it is not easy to point out specific distinctions, the static character of the genus makes the continuance of a species during the interval between the horizon in question and that of the Warsaw possible.

Rhynchonella sageriana, Win.

(Perhaps a variety of R. sappho, H)

Shell rather gibbous, thickness equal to more than one-third the width, transversely extended; ventral valve broadly oval to slightly pentagonal, with a pointed incurved beak; mesial sinus rather distinct, narrower than one-third the width, extending less than half way to the beak, with three to four strong plicæ; lateral surfaces convex, with five or six plicæ on either side, which rather rounded above; lateral margins nearly straight, meeting the beak at an angle of about 110°; length of lateral margins greater than half the length of the valves, intersecting the evenly-curved ventral margin at a point in front of the middle; concentric striæ or folds appear near the front; hinge plates sub-parallel, over one-seventh the length of the valves. Length to width about as seven to eight. Width 24 mm, height 20 mm; (21–17; 18–17; 21–18; 18–15; 23–20.)

Dorsal valve more nearly quadrate or sub-circular; beak short and incurved; casts showing a strong median plate within; antero-lateral outline semi-circular, postero lateral angle very obtuse, mesial fold inconspicuous, with four or five plicæ, lateral areas with four to six plicæ. Length to width as 4–5.

The specimens vary in many respects, but in no specimens were the mesial plicæ more than four or five, there being three in the sinus and four on the fold in normal adults. Two varieties exist side by side, differing only in the number of plicæ.

The second agrees very closely with R. sappho in some of its varieties.

This species belongs in the sandy layers or flags about 40 feet below congl. I, where it is abundant. The Granville specimens are said by Prof. Winchell to be typical. This is No. 1313, of our Museum Register and has now for the first time been described in full. Our own belief is that all of the closely allied forms belonging in this section of the genus are conditions of a single species—R. sappho.

Rhynchonella sappho, Hall.

(Plate V, Fig. 1; Plate VII, Fig. 25.)

Of large size, agreeing in outline with *R. sageriana*, but with more numerous plicæ, there being generally five in the sinus and six on either side. It is possible to duplicate the Hamilton forms exactly from our collection.

Found in the free-stone of middle Waverly, and also in free-stones from a horizon 60 feet above congl. II, that is in the upper Waverly.

Some of the varieties of this type resemble R. cooperensis, perfectly.

Rhynchonella marshallensis, Win.

This species is recognized by the ventricose, flattened dorsal valve with numerous (20–28) rounded plicæ, broad fold with six or seven plicæ, and the sudden flexture of the front and lateral margins. The species ranges through the middle Waverly.

Several other species could be recognized, but it is feared that a larger collection would obliterate the distinctions assumed.

Atrypa reticularis, ? ?

(Plate III, Fig. 11.)

Small specimens resembling this species have been obtained from the upper free-stone, lower part of division III. The identification is doubtful, though undoubted specimens said to have been derived from the Waverly are in the museum of Ohio State University.

GENUS SYRINGOTHYRIS, Winchell.

(*Syringothyris cuspidatus,* Martin.

(Plate I, Fig. 7, (?); Plate II, Fig. 17; Plate V, Figs. 4–7.)

Anomites cuspidatus, MARTIN, 1796.
Spirifer cuspidatus, SOWERBY, 1809.
DAVIDSON, 1857.
Cyrtia simplex, McCOY, 1884.
Cyrtia cuspidata, McCOY, 1855.
Spirifer capax, HALL, 1858.
Spirifer carteri, HALL, 1857.
Syringothyris typa, WINCHELL, 1863.
Spirifer textus, HALL, 1857.
Spirifer hannibalensis, SWALLOW. (?)

It seems to me after a careful collation of the descriptions above quoted and the comparison of several hundred specimens that a due conservatism will unite all the supposed species and identify them, as positively done by Davidson and Dekoninck, the most careful European authors, with S. cuspidatus. The wide range of variation and distribution make this an exceedingly valuable species for approximately synchronizing widely distant horizons, for its vertical range is not extraordinary. The subjoined table of measurements and data will serve our present purpose in connection with the figures. In the view here indicated Prof. Winchell does not concur, as may be gathered from the extract from a private letter of Jan. 9th, 1888, from which I take the liberty to quote.

"I have heretofore identified with this species some specimens from Newark, Ohio, embracing both ventral and dorsal valves. I received some time since, from Prof. Hicks, specimens from Granville, labeled *S. Carteri*, among which is a ventral valve resembling forms identified by me with *Syringothyris typus*; but his dorsal valves differ from those of *S. typus* in having the hinge extremities prolonged and pointed; in more rigid costæ and lack of situation in the middle of the anterior margin. They also lack the deep concentric wrinkles of the dorsal valve of *S. typus*. I hence separate these dorsal valves from Granville from *S. typus*, and leave them to represent *S. Carteri*."

Fig. 17, of Plate II, serves to illustrate the usual form of the smaller and more finely striate form called S. carteri, though these often have acuminate angles. The difference between such forms and those of Fig. 14-15 Plate V. is not completely bridged, nor does it seem possible to exclude the extreme variety drawn in Fig. 7, Plate I.

The species reaches its maximum in the congl. II, but is characteristic of the middle division, beyond which it extends somewhat both above and below.

Spirifers of the S. marionensis group.

This is the most perplexing subdivision of the genus. Four nominal species contend for admission and present characters so concordant as almost to baffle discrimination. These species are *S. striatiformis*, Meek, *S. centronata*, Win., *S. biplicatus*, Hall, and *S. marionensis*, Shumard. All of these have been at some time identified in Ohio. S. striatiformis alone presents such peculiarities as make it easily identified when perfectly preserved. The S. biplicatus described by Meek in the Ohio Palæontology is stated by Winchell to be his S. centronata, thus eliminating a second from the set. The following tabular arrangement based on the original descriptions will afford the basis for comparison. The following order being preserved:

1. S. striatiformis, 2. S. centronata, 3. S. marionensis, 4. S. biplicatus.

Species.	Hinge.	Lateral extremities.	Ventral beak.	Ventral area.	Foramen.	Ventral sinus.	Dorsal fold.
1	Shorter.	Rectangular	Pointed, curved.	Mod'rate, arched.	Wide	Narrow, deep	Narrow, low.
2	longer.	acute.	"	"		"	"
3	"	"	"			"	"
4	"	" !	"	Narrow.	Wide	"	"

	Striæ	Striæ on fold.	Striæ on sinus.	Number of striæ on valves.	Surface ornaments.
1	Numerous, small, round, bif'rc'ting	8	8	56	Minute striæ
2	"	—	3—5	36—40	
3	"	—	3—4	50	
4	"	6		80	

Between S. marionensis and S. centronata it is very hard to discover any point of dissimilarity. In fact we cannot distinguish specimens from the Cuyahoga shale, the locality of S. centronata, from specimens of S. marionensis from near the middle of the lower division of the Waverly in Licking Co. S. striatiformis is restricted to the upper portion.

Spirifer marionensis, Shumard.

(Plate VI, Figs 2-4; Plate VII, Fig. 11; Plate IX. Fig. 1 ?)

Cf. *S. centronata*, Win.

Our figures give a good idea of the range of variation exhibited, though in the smaller shells the mucronate extension of the hinge is more marked. On the largest shells there are rarely more than four plicæ on the fold or sinus and the lateral margins are usually quite oblique. This species has been found in the shale near the east end of the bridge crossing Moot's run, four miles west of Granville, and the layer of nodules one mile west. The horizon being supposed to lie at least sixty feet below congl. I. Shell nearly semi-circular; moderately convex; length 4-3-2½ times the height; valves of nearly equal convexity. Hinge-line considerably extended with acute ears, which are sometimes mucronate. Ventral valve convex with a rather prominent beak and strongly curved striated area; greatest convexity near the beak; lateral portions depressed; sinus narrow, but rather deep; surface marked by 40 rounded plicæ which are dichotomous, and of which about four occupy the sinus, which is triangular in section, especially near the beak. Area moderately narrow and strongly inclined, with a broad triangular area which is striate. Dorsal valve only moderately convex, laterally depressed, most convex above the middle, fold very inconspicuous, scarcely elevated, with two pairs of plicæ produced by bifurcation of the two primary ones. Dichotomy of striæ of both valves very irregular. Surface concentrically striate, sometimes with concentric folds also. Found in the lowest horizon of Licking Co. Its range being 20 feet, so far as observed.

This species was first described from the so-called Chemung of Missouri. Later, Prof. Hall, in his Iowa Report describes specimen from rocks of the Hamilton age, while Prof. Winchell noted its occurrence in Waverly strata, at Sciotoville, O.

The casts show peculiar internal structures which may be of assistance in destinguishing the species.

Spirifer striatiformis, Meek.

(Plate III, Fig. 26; Plate VI, Figs. 6-7.)

Undoubted and typical specimens are found in our upper Waverly, well toward the summit of the series. The illustrations in the third volume of the Ohio Palæontology convey a good idea of this shell. Isolated dorsal valves, however, resemble the shell called in Ohio, S. carteri, and are sometimes so-called. Eight to twelve plicæ occupy the mesial fold. The fine radiating striæ, when preserved, are good specific marks.

Shell of medium size; semi-oval in outline, only moderately convex mesially, rather flat toward the sides; hinge-line equal to greatest width or sometimes less, often slightly mucronate; lateral margins generally making with the hinge-line about a right angle. Ventral valve much more convex than the dorsal; beak strongly incurved;

cardinal area arched, striate parallel to the hinge line, foramen ¼ to 1-5 as wide as the hinge; mesial sinus rather narrow and ill-defined, triangular in section, continuing to the beak; interior with short, diverging dental lamellæ and small rostral cavity. Dorsal valve quite flat, except the rather low, ill-defined, triangular fold; beak projecting beyond the hinge-line; area narrow, striate *at right angles* to hinge-tine. Surface of both valves covered by numerous small, low, rounded costæ, which bifurcate somewhat irregularly and are marked by numerous radiating striæ and, less obviously, by concentric striæ as well as the usual lines of growth. (The cancellated appearance spoken of by Meek is rarely observed, while the radiating striations are quite noticeable. Sixty-five to seventy-five costæ are found on a valve of medium size, from eight to fifteen occupying fold and sinus. The typical form is found near the summit of the Waverly, about 100 feet above congl. II, with *Productus semireticulatus*. This layer occurs at at the very top of the exposure at Rushville and cannot be far below the Chester limestone.

In conglomerate I, are found specimens apparently intermediate between the previous species and S. striatiformis, but more convex than either. In the free stone still above is another variety which is with less doubt referred to S. striatiformis. Specimens are figured on Plate VI, Figs. 6, 7. These have a broader sinus and more nearly quadrate form, though short mucronate ears are retained.

If S. centronata is a valid name for the form from Cuyahoga shales the relation between that species and S. marionensis must be left for future study. The close relation of all these to S. disjuncta of the Chemung is noteworthy.

Spirifer biplicatus, Hall.

Not *Spirifer biplicatus*, Meek, O. Pal. Vol II.

But a single dorsal valve has been encountered with the characters of S. biplicatus, indeed, we suspected the validity of the species. It may be confessed that a wider range of observation may invalidate the assumed distinctions. This dorsal valve differs from those of S. striatiformis, with which it is associated, in the greater distinctness of the plicæ, and the depressions bordering the median fold, and by the fact that the plicæ on the fold are so much smaller than those of the rest of the surface. The surface is also more convex. There are about 28 pliæ, four being on the fold and those of the general surface are simple, while those of the fold dichotomize. This species is smaller than S. striatiformis. Division III, near Newark. W. F. Cooper, collector.

Spirifer winchelli, sp. n.

(Plate V, Fig. 2–3; Plate II, Fig. 16.)

Most nearly resembling S. mesacostalis. Shell transversely elongate, gibbous; width from two to three times the height. Ventral valve quite convex mesially, strongly and evenly arched from the closely incurved and projecting beaks to the lower margin. The area is very narrow; hinge-line usually strongly produced, lateral angles mucronate; surface marked by about 15 rounded plicæ on either side of the deep triangular sinus. (In one case a trace of slight fold in the bottom of the sinus was discovered, but, as all our specimens are casts, these might not usually be preserved if present. Dorsal valve less gibbous; area very narrow, beak minute; surface most convex near the middle; fold high, strongly defined, narrow, marked in the center by a deep groove. Surface ornamented by lamellose concentric lines. The close relationship with S. mesacostalis of the Chemung require no comment. If the strata were adjacent the two would hardly be separated. A considerable number of closely agreeing specimens were found in conglomerate II, at Granville. Named in honor of the distinguished state geologist of Michigan.

Spirifer sp (Cf. *S. raricosta*, Con.)

(Plate I, Fig. 5.)

A small species of Spirifer, resembling Spiriferina somewhat, or more nearly the species quoted above, is represented by the single fragment from an unascertained portion of the Waverly. As the species in question belongs to the corniferous horizon and ours has a greater number of plicæ, it is improbable that they should proue identical.

Spirifer? hirtus, M. and W?

(Plate III, Fig. 2.)

A single dorsal valve may represent this species. A similar form from the Cuyahoga shale has been referred by collectors to S. setigera, H. The existence of such an Athyris-like form is of interest even though some doubt must prevail as to the specific relations. To the student of evolution the series beginning with the Devonian and including *S. fimbriata*, *S. præmatura*, *S. pseudolineatus*, *S. setigera*, *S. lineata*, etc. should be interesting.

Cyrtina, *sp.*

(Plate VIII, Fig. 18.)

A small species is known from a ventral valve found in calcareous nodules at the base of the Licking Co. section at Moot's run, four and one-half miles west of Granville. Height 4 mm; width 5 mm; convexity 2 mm; beak slightly incurved; sinus narrow, rather deep: about seven plicæ on either side. Our form is less elevated than C. acutirostris, Shumard, resembling S. hamiltonensis, but with a narrower sinus.

Spiriferina solidirostris, White.

(Plate II, Figs. 9-11; Plate V, Fig. 13.)

This pretty little shell is common in a layer of free-stone several feet above congl. II, at Newark. All specimens so far collected are very small and are characterized by the high incurved beak of the ventral valve and the regular concentric striæ, which in well preserved specimens cross the few plications. The dorsal valve is rather flat, with a small beak and 7–9 rather large folds separated by deep, but not wide grooves. The median fold is flattened or even channeled above.

Spiriferina depressa, sp. n. (?)

(Plate 10, Fig. 3.)

Shell of large size, valves nearly equally convex, transverse, the hinge-line equal to the greatest width.

Ventral valve wider than high, moderately convex, beak incurved, not greatly elevated beyond plane of hinge, the extremities of which are met by the lateral outline at about a right angle. Surface marked by about twelve (8–12) sub-equal rather distant plicæ and concentric, irregular ridges, mesial sinus not so well defined and enlarged as usual. Dorsal valve of the same general form, but somewhat less convex and with less prominent beak; median fold, moderate and somewhat flattened, with about five plicæ on either side.

This species is known from a single gathering, but a considerable number of specimens of quite constant characters. It differs from the preceding not only in greater size, but in the much less convexity and projection of the beak and in the more transverse and square-shouldered form.

Height 11 mm ; length 17 mm.

Small specimens have fewer plicæ, but otherwise are similar. From one mile north of "Dug-way," apparently below congl. II.

Genus Terebratula.

Subgenera Cryptonella and Centronella.

The distinctions which separate the genera Cryptonella and Centronella from Terebratula are of such a character as can readily be referred to slight modifications of the structures characteristic of the last named genus. It seems expedient, especially in view of the admitted impossibility of distinguishing these groups without a knowledge of the internal structures, to regard them as subgenera of the large and characteristic genus Terebratula.

Cryptonella eudora, H.

(Plate V, Fig. 10.)

"Shell broadly ovate, rounded in front, apex obtuse. Ventral valve gibbous in the central and upper part, moderately convex in the lower part, and sometimes flattened toward the front; tapering abruptly to the beak, which is obtuse, little extended beyond the opposite valve, slightly incurved, and truncated by a rounded foramen. Dorsal valve depressed-convex, often gibbous in the middle above; beak incurved into the cavity below the deltidial plates. Surface concentrically striate with crowded lamelliform ridges toward the sides and front."

Length of our largest specimens nearly 30 mm, width 27 mm. Varying greatly in form and size. The casts figured on Plate V give a good idea of the vascular markings.

Freestone of middle Waverly. Typical specimens are from the Chemung of New York.

Centronella julia, Win.

(Plate II, Fig. 5.)

Shell small, lenticular, ovate or somewhat transverse in outline; valve moderately convex, its beak covered by the higher, incurved beak of the more convex ventral valve; area absent. Surface marked by concentric lines of growth and radiating lines (impressed from the interior upon the cast?) Internal characters of the genus.

Many specimens of this species may be found in the freestone overlying shales above congl. II, at Newark and eastward. It agrees in external feature perfectly with Prof. Hall's figures of this species. Other forms are illustrated in figures 4 and 8 of Plate II, and may be refered to this genus. As, however, we know nothing of the essential characters we may forbear burdening synonomy with meaningless names.

Athyris ohioensis, Win.

(Plate II, Fig. 1.)

Some doubt attends the identification, on account of the condition of our specimens, but Prof. Winchell was good enough to compare our casts with the types and considers the identification as a probable one.

Athyris lamellosa, Leveil.

(Plate II, Fig. 7.)

The specimens figured are from the layer below congl. I, and we are at a loss for any sufficient distinctions between our form and the species quoted. A large species of Athyris is also found in the nodules at Moot's run, which apparently differs from the one quoted. The resemblance between the Devonian and carboniferous members of this genus is too close to make a separation easy at present.

The small species Figs. 19, 34, Plate VII, may be an Athyris or an Amphigenia resembling A. elongata. Congl. I. The affinities of Fig. 21 of the same plate are still more obsure.

Aviculopecten perelongatus, sp. n.

Left valve extremely elongate, narrow and quite convex along the longitudinal axis. Height to length of body as 1½ to 1. Body acutely narrowed toward the curved beak, the sides forming an angle of less than sixty degrees. Posterior wing small, triangular, rather acute. Surface marked by very numerous crowded, hair-like, sharp striæ, which bifurcate and increase by intusuception irregularly, also by concentric folds, which are more distinct toward the sides. The wings have less numerous radiating striæ. The convexity of the valve is greatest near the middle and forms almost a fold along the longitudinal axis, sloping regularly to either margin. The umbonal slopes are both concave and rather abrupt.

Such a brief description of a single imperfect valve would not have been offered except that the form is so unlike that of any known species as to make it unmistakable. Perhaps A. dissimilis Fl., as identified by Toula, from Spitzenbergen, approaches it most nearly in outline, though our species is much more elongated. It does not appear possible that the peculiarities can be to any extent due to distortion. Length 24 mm, width 15 mm, posterior ear 5 mm. Number of striæ in one mm, 3 at the lower margin.

Freestone of middle Waverly.

Aviculopecten (*granvillensis*, sp n.)

(Plate X, Figs. 8; Plate XII, Fig. 11.)

Cf. Aviculopecten amplus and A. crenistriatus.

An imperfect left valve and fragments of a right valve suggest very close relationship to A. amplus of the Keokuk of Ill.

From this species our left valve differs in the form of the anterior ear, which is less projecting. The posterior ear is broken, but evidently is very slightly defined. The valve is quite flat and is marked by distant, irregular and somewhat alternating striæ. The surface markings are poorly preserved in our cast.

A faint impression of the right valve of apparently the same species closely resembles in ascertainable characters that of A. amplus. It is quite flat and almost destitute of markings. The anterior ear is evidently very distinct from the body and separated from it by a deep byssal sinus. The posterior ear is minute and ill-defined. Length of left valve 77 mm; width 81 mm; hinge 53 mm.? Length of right valve 48 mm. This species occurs in some hitherto unidentified horizon evidently of the Freestone of middle or upper Waverly.

In this connection should be mentioned a large species known only from a single fragment secured near the very top of the Waverly (ten feet below coal-measure congl.) 8 miles east of Newark. This fragment (Plate XII, Fig. 21) is nearly as large as the above but, if a left valve, as seems probable, must be very dissimilar in outline. The alternation and irregularity of the striæ are even more pronounced than in the above, but the striæ are apparently higher and are crossed by innumerable very fine concentric striæ. In some respects this form resembles A. crenistriatus.

Aviculopecten cooperi, sp. n.

(Plate XII, Figs. 16–17.)

A beautiful species, found too late for careful study, differs from all others from the Ohio Waverly in its markings. Closely agreeing with A. sub-cardiformis, Her., in outline, but much less convex. Left valve somewhat longer than wide, posterior ear of moderate size, not sharply set off from the body; surface of valve and ear covered by very fine, rather uniform, but irregularly waved striæ, crossing shallow concentric folds; about 4 of the radiating striæ occupy the space of 1 mm; anterior ear not seen. A fragment of what seems to be the right valve of the same species accompanies it. This valve is less convex and is marked only by very fine concentric striæ, except upon the posterior wing, which has the form and markings of that of the left valve; anterior wing long, acute, separated from the body by a deep byssal sinus and steep umbonal slope. Length of left valve 16 mm; width 15 mm; length of hinge 10–12 mm.

Nodule layer, Moot's run. Collection of W. F. Cooper.

Aviculopecten (Cf. *oweni*, M. and W.)

(Plate III, Fig. 5.)

Shell small, subcircular, lower margin nearly equally curved to points nearly half way to the beak, here suddenly flexed to meet the lateral margins, the anterior one in the left valve being slightly concave, the posterior a little convex; beak prominent; hinge line somewhat less than the width; anterior ear rather large, obtusely angled; posterior ear smaller and more acute and rather less sharply defined; surface quite convex, greatest convexity being about one-third from the beak, ornamented by rather numerous bifurcating and implanted striæ, of which about fifty can be counted on the body of an average shell. Length 10 mm; width 10 mm; length of hinge 8 mm. The difficulty of comparing this species with A. oweni is increased by a doubt as to which valve is figured by Meek and Worthen. The description states "right valve unknown," while the figure is stated to be that of the right valve. If it be a left valve and our own are likewise left valves, the relation of the ears is reversed. Our species is smaller, but otherwise resembles the Illinois form. None of the species quoted by Winchell as from the Waverly and its equivalents, seem to be identical with this, though it may prove the young stage of one of the common ones, perhaps A. winchelli. The horizon is the same as in that species, the free-stone of middle Waverly.

Aviculopecten (*Crenipecten*) *newarkensis*, Win.?

(Plate III, Fig. 31.)

A single right valve may belong to this species as indicated by its rather narrow form. As Winchell's specimens were all left valves, the identification can only be conjectural. Length 18 mm; width 15 mm. Valve very flat, covered by irregularly alternate, rather filiform striæ. Umbonal slopes about 90° or less.

Crenipecten sub-cardiformis, sp. n.

(Plate VII, Figs. 4–5)

Cf. *Aviculopecten caroli*, WINCHELL, 1863, pars. ?

[Wrongly quoted above as C. tumidus.]

We have been caused a great deal of perplexity by this species, which occurs by scores in our collection. It is chiefly restricted to a zone about 40 feet below congl. I. though it ranges upward to a horizon just beneath it in company with streblopteria media. Aviculopecten caroli, Winchell, would not be considered in this connection were it not for the statement made by Prof. Winchell, in 1870, that it was found at Granville, but that the specimens from that locality "were all right valves, and are much flatter than typical specimens of the same valve." On the whole it may be safer to regard our form as a distinct species unless a comparison of types proves this not to be the case. Shell of medium or small size, nearly circular, height and length equal, with well-defined and depressed ears. Left valve very ventricose, hinge slightly shorter than extreme length; lower margin a nearly circular curve intersecting the auricular margin at about two-fifths the distance from the hinge to the lower margin; anterior ear rather large, greatly depressed below the adjacent portion of the body, from which it is separated by a sudden deflection; posterior ear less sharply defined, but nearly equally as large and not separated by a well-defined sinus from the body, depressed; beak high, but incurved and acute, projecting slightly beyond the hinge; greatest convexity near the union of the upper and middle thirds; surface marked by from thirty to forty strong, very irregular, radiating costæ, alternate ones being generally smaller and originating by implantation or, more rarely, bifurcation; these costæ are crossed by fine, close, but irregular concentric striæ, which do not cross the larger costæ, and distant undulations; the anterior ear bears about six costæ, while the posterior ear is nearly smooth, but exhibits more plainly the concentric striæ; rarely two small costæ occupy the space between the larger radiating ribs. The right valve is very flat and nearly without markings; the hinge is longer than or equal to the greatest length and the ears are very large; and nearly equal; the anterior ear is set off by a deep depression from the body and the valve is provided with a deep byssal sinus below the ear; the posterior ear is less sharply defined by the umbonal ridge, but is lower than the plane of the body and its margin passes into that of the valve by a moderate curve. Although both ears are provided with well defined radial and concentric striæ none appear clearly in any of the specimens on the body of the valve. The hinge of the left valve is crenulated as in A. winchelli, which the right valve resembles. The very convex left valve and surface characters serve to distinguish it from other species.

Height 14 mm; length 14 mm; length of hinge 11 mm.

Crenipecten senilis, sp. n.

(Plate III, Fig. 1.)

The limited number of aviculopectenidæ found in the Waverly induces me to propose a name for this species known only from the left valve.

Shell of medium size, nearly circular or elliptical in outline; rather flat. Left valve slightly convex, with a moderately acute depressed beak; anterior wing large, separated from the body by a moderate umbonal ridge, its outline passing into that of the body by a flowing sigmoid curve; posterior ear obsolescent, obtuse, entire posterior outline a gently convex curve slightly straightened near the hinge. Surface marked by large, very irregular, convex, rounded plicæ which increase without regularity by subdivision into a small and large plica or the plicæ are proliferous without sensible diminution of size of the primary one. The anterior ear is similarly plicate and, like the body, is crossed by fine concentric striæ. The plicæ are separated only by a deep, narrow, angular groove. Length 29 mm, width about the same; anterior ear 8 mm.

The single specimen seems to have been derived from the freestone. The peculiar markings serve to distinguish this from the other known forms. It bears a close resemblance in outline to Streblopteria media.

Aviculopecten (Lyriopecten ?) cancellatus, sp. n.

(Plate XII, Fig 7.)

Shell small, suborbicular; length and height equal; lower and lateral margins uniformly rounded. Right (?) valve moderately convex, hinge four-fifths the greatest length; beak nearly central; anterior wing small, ill-defined; posterior wing larger, separated from the body by an oblique plane surface, rather flat; no indications of a byssal sinus. Surface finely cancellated by uniform, high, regular radiating and concentric ridges, the latter sub-imbricating. There is little to determine which valve our single specimen represents, it may quite possibly prove to be a left valve. There is some resemblance to small specimens of L. orbiculatus. The most that can be said is that our shell possesses a decidedly Devonian aspect. Nodule layer at Moot's run.

Linatulina (?) *ohioensis,* sp. n.

(Plate II, Fig. 20; Plate III, Fig. 10.)

Shell of moderate size, obliquely and rather narrowly oval; height over one-fifth greater than length; hinge line very short; surface with distant, irregular furrows. Left valve moderately convex near the beak, elsewhere quite flat, with hinge line equal to about one-half the greatest length; valve not very oblique, umbonal ridges meeting at the beak at less than a right angle, beak somewhat acute; anterior ear well-defined, but small, rounded and separated from the body of the valve by an abrupt descent, its margin concavely sinuated below; posterior ear very small and obtuse. The posterior margin makes a broad curve which is straightened above, but curves more rapidly in passing into the very convex front outline. The valve is marked by about 20 distant and very irregular narrow and deep radiating striæ and folds. Right valve very oblique and short, hinge line relatively longer, posterior margin straight, making an angle with the hinge of about 130°; posterior angle produced; anterior ear small, convex, projecting, separated from the valve by a profound acute byssal sinus; marked by about four or five distinct costæ; markings of the body as in the left valve. Evidently the shell was quite inequivalve.

Height of perfect left valve 20 (23) mm; lenght 15 (18) mm; hinge 9 (8) mm; height of right valve 12 mm; lenght 10 mm (?); hinge 8 mm.

A number of specimens have been secured only one of which, unfortunately, was a right valve. The shell is so thin as to make it peculiarly liable to distortion. The species is normally somewhat longer than that drawn on Plate III. Though the hinge was not seen, this species seems allied to Limatulina than any other genus of the family. Confined to the strata above congl. II, chiefly near the very top of the Waverly as exposed in the county.

Streblopteria media, sp. n.

(Plate III, Figs. 8–9.)

(Cf. *L. similis*, Walcott.)

Closely allied to *S. similis*, Walcott, of medium size, rather broadly ovate, not oblique, moderately convex near the beaks.

Left valve most convex, anterior ear broadly rounded, depressed, separated from the body of the body of shell by an abrupt inclination, sinus moderately concave, remainder of the margin a rather regular convex curve approaching a straight line near the point of union with the hinge, which is short, and not forming a well-defined posterior ear; beak acute, somewhat projecting; greatest convexity a short distance from the beak; surface marked by rather distant and coarse, but inconspicuous radiating striæ, or apparently smooth. The right valves differ little in form, but the byssal sinus is very sharp and deep and the anterior ear is long and rather prominent and separated from the body of the shell by a deep groove. The posterior ear is obsolete. The surface is nearly smooth, except the anterior ear which is very strongly marked by radiating striæ.

From *S. similis* this species differs in being relatively broader, especially in the left valves, and lacking the fine striations seen in small specimens of that species. It resembles very closely indeed, *Crenipecten foerstii* of the coal-measures, but differs from it in the proportions of the ears and does not seem to possess the crenulated hinge. The only other American species with which comparison is necessary is *S. tenuilineatus*, from the coal-measures of the West.

Height of a right valve 16 mm; greatest length 16.8 mm; length of anterior ear 7 mm; distance from hinge line produced to anterior angle of shell below byssal sinus 5 mm. Height of a left valve 19 mm; length 19 mm; length of anterior ear 6 mm; greatest length at about 10 mm. from beak. Numerous closely agreeing specimens from the layer a few feet below congl. I. The species is also found forty feet below congl. I, at Union Station, in large, finely preserved specimens, a left valve measuring in length, 25 mm, in width 23.5 mm.

Streblopteria squama, sp. n.

(Plate VII, Fig. 14.)

Smaller or medium size, with extended hinge-line and ovate outline. Left valve quadrately ovate; length and height about equal; hinge about three-fourths the length; anterior outline nearly straight, slightly convex below and concave at the ear; posterior outline gently and uniformly convex; anterior wing largest, nearly rectangular, not very distinctly separated from the body; moderate posterior ear obtusely angular, passing without interruption into the general surface of the body; surface slightly convex, ornamented only by fine, crowded imbricating lines, epidermis very thin. Shales below congl. I.

This species is considerably smaller than the average specimens of S. media and is more broadly ovate, with a longer hinge-line. No traces of radiating striæ could be seen.

Streblopteria gracilis, sp. n.

(Plate VII, Fig. 12.)

Shell of medium size, elongate, with very short hinge.

Left valve narrowly elliptical, length four-fifths the height, hinge less than half the length; posterior margin a uniform slight curve to the almost obsolete ear: anterior margin very abruptly flexed at the umbonal slope to the short, obtusely triangular ear; surface convex, ornamented by concentric and obscure radiating lines. Free-stone of middle Waverly (?) This species resembles the larger form of S. media, but is at once distinguished by its narrower form and short hinge-line.

Pernopecten shumardianus, Win. ? ?

(Plate XII, Figs. 13-5.)

A considerable number of nearly perfect valves are represented in our collections from the nodule layer at Moot's run. Our largest specimen agrees in all preserved characters with the species quoted doubtfully as P. shumardianus The opposite valve is more nearly flat and was poorly preserved. The great vertical range of this group as well as the perplexing relations of the genera Pernopecten and Entolium make it difficult to base conclusions upon their distribution. Compare Bulletin Denison University, Vol. II, p. 23.

Pterinopecten cariniferus, sp. n.

(Plate XII, Figs. 8–9, 42.)

Shell small, sub-rhomboidal, slightly oblique; greatest length (of body) below or at about the middle of the valve; length from one and one-fourth to one and one-fifth the height; lower margin nearly even elliptical curve, becoming rather rapidly flexed behind till its direction makes a little more than a right angle with the hinge, which it meets by a gentle outward curve; anterior margin abruptly curved above the middle, forming an angle of about 45° with the hinge, to the deep byssal sinus. Right valve slightly convex; hinge-line straight longer than the body, acute at both extremities; beaks low, situated at about the anterior one-third; posterior ear or wing large, triangular, depressed, but not distinctly outlined from the valve, anterior ear acute, produced. Left valve more convex; beak slightly projecting; surface marked by regular distant radiating ribs and distant concentric folds, producing a pretty cancellation. The radiating markings of the right valve are less conspicuous.

This species has a distinct Devonian habit. Nodules in shale at Moot's run, 4½ miles west of Granville.

The right valve is very like some states of Pterinopecten vertumnis. The resemblance is close to Pt. exfoliatus, but the ear is too small in that species.

Pteronites (Leptodesma) ? obliquus, sp. n.

(Plate VII, Fig. 7; Plate IV, Figs. 20.)

A very oblique species occuring in the free-stone of the middle Waverly may be recognized by its great obliquity and convexity. The anterior projection is apparently acute, the lower margin forming an angle of 30°-40° with the hinge. The posterior wing is imperfect, but was probably slightly produced. Fig. 20 of Plate IV, is certainly wrongly restored, being, without doubt, the same species as the one first referred to. The relation to certain Chemung species, especially Pt. inoptatus, is very close.

Leptodesma (?) *scutella*, sp. n.

(Plate IV, Fig. 16.)

A number of specimens of a little shell at first referred to Pteronites indicate a species belonging to section umbonata, but apparently distinct from any Chemung species. Sub-rhomboidal or nearly semi-ovate, anterior wing short, acute; body inclined about 50° to the hinge line, which it about equals; posterior margin concave, upper angle produced, beak sub-anterior; surface gently convex, except the posterior wing, marked by equidistant lines of growth. With the above.

Posidonomya (*Streblopteria*) *fragilis*, sp n.

(Plate VI, Fig. 1.)

The specimens on which this species is founded differ from all Waverly species and all others known to me. The species may be compared with P. laterugata, but is less alate and has much more prominent beaks.

The wings are almost too prominent for a member of the genus quoted and the presence of indistinct radiating striæ passing over the coarse plications adds to the incongruity.

The right valve is broadly oval or nearly circular, with the posterior ear considerably produced, anterior one less distinct and shorter, margin below the ears a reniform broad curve resembling a circle; surface of the valve rather flat, but somewhat suddenly elevated near the beak, which is acute and slightly projecting beyond the hinge; hinge line straight, rather short; surface marked by distant irregular folds and indistinct, fine, minute radiating striæ. Height 29 mm;

greatest length 31 mm. Found at Moot's run, four miles west of Granville, in nodules at the very bottom.

Promacra (?) truncatus, sp. n.

(Plate III, Fig. 30.)

Without absolute certainty that this species can be properly referred to Promacra, it remains certain that a very peculiar species exists with a general resemblance externally to the assemblage so designated. Our specimen is incomplete and doubtless distorted, though the peculiarities thought to be due to pressure may be inherent. Shell elongate, produced anteriorly; beaks in front of or near the middle; strongly convex (in our specimen the transverse section is broadly cordate.) Dorsal margin in front of the beak straight; hinge extending a short distance behind the beak; posterior margin very oblique, meeting the nearly straight ventral margin at a very acute angle, at or near the lowest part of the shell; (anterior extremity not seen); post umbonal ridge very strong, acute; plane of the post umbonal slope at right angles to the sides of the shell, plane or somewhat concave, giving the shell a curious truncate appearance; surface marked by strong irregular furrows and striæ, which in passing over the post umbonal ridge make a very acute angle; beaks incurved to the plane of hinge; shell gaping widely behind, apparently closed or nearly so anteriorly. Allowing for all probable distortion the shell seems distinct from all others. It could not have been so extended anteriorly as *P. andrewsi*, nor as strongly marked as *P. nasutus*, though some indications of the radiating striæ of that species, which ours most resembles, can be seen.

The three known species are all from the same relative horizon. *P. missouriensis*, from the sub-carboniferous rocks of Missouri, *P. nasutus*, from Choteau limestone of the same state, and also in Belgium, while P. andrewsi was found by Meek, in the Waverly group of Ohio.

Leiopteria ortoni, sp. n.

(Plate VII, Fig. 1.)

Shell of medium size, triangularly ovate to subrhomboidal; body obliquely ovate, length considerably exceeding the height; post basal side considerably extended; ear straight, almost acute, anterior side obliquely truncate; body making an angle of about 45°, with the hinge line. Left valve shortest, most gibbous; beak one fourth from anterior, rather prominent, but not incurved, ear rather convex, with a broad shallow byssal sinus, wing large flat, the posterior margin meeting the hinge at an angle of about 90° or more, acute at the very angle only. The hinge margin is greatly thichened. The difference between the two valves is slight, the beak of the right being generally in advance of the other, and the front margin is more uniformly curved.

Entire length of hinge linge 22 mm, height 14 mm, length from beak to antero-ventral angle 19 mm. Surface marked by concentric lines. This species somewhat resembles L. rafinesquii, H., but differs in being more oblique and longer, with straighter and longer hinge and less produced beak and straighter posterior margin. Leptodesma hector is somewhat more like our species, but exhibits an opposite extreme. This species is characteristic of a zone several feet thick, about 40 feet below conglomerate I, in connection with other fossils of a more or less Devonian habit. This species may be compared with L. torreyi, but is not so produced; it also resembles Leptodesma nereus. Compare also L. naviforme.

Leiopteria halli, sp. n.

(Plates VII, Fig. 31, Cf. Fig. 32.)

Shell of moderate size; sub-rhomboidal; body narrowed above, obliquely ovate; height greater than length at hinge; margin strongly sinuous; ears rounded, somewhat depressed, short; wings broad, extended, acute; hinge-line straight. Valves nearly similar, left valve rather more convex. Right valve moderately convex; body diverging from hinge-line at an angle of about 45°; wing acute; posterior margin strongly concave, postero-ventral extremity rather sharply curved; anterior margin abruptly flexed near the middle, anterior to which it is gently concave; ear rounded, depressed. Left valve with smaller wing more convex, especially ventrally. Surface of both valves marked by conspicuous concentric folds. Hinge with a decided groove and thickened ridge. Beak of right valve high, but not projecting dorsally, that of the left valve extending beyond hinge-line.

Length of right valve from beak to postero-ventral convexity 17 mm; hinge posterior to beak 13 mm, height 13 mm; greatest diameter (from ear to postero-ventral angle) 19 mm. This species is intermediate in characters between *L. ortoni* and *L. rafinesquii*. Like the latter the wing is acute and the posterior margin excavated, like the former the body is very oblique. Top of freestone, Granville.

L. halli may be compared with Leptodesma clitus, H., but is not so produced behind and rather less oblique, it is also less oblique than L. lepidum. Perhaps the closest resemblance is with Leptodesma lysander, but the wing is not so extended.

Leiopteria, sp.

A very small species of this genus was secured from the lower shaly layers at Moot's run, probably below the horizon of L. ortoni, but which more nearly resembles L. halli in the acute wing and excavated posterior margin. The species is known only from a single right valve with a short, lobate, obtuse ear. The body is more oblique and narrower than in either of the preceeding species.

Prof. Hall states that only two of the fifty-seven species of Leptodesma occur below the horizon of the Chemung, Leiopteria, on the other hand, reaching its greatest development in the Hamilton. Pterinopecten has many species below the Chemung, while Crenipecten and Pteronites are unknown below. Glyptodesma is not known above the Hamilton.

Leiopteria sp ?

(Plate III, Fig. 6)

A fine large species is indicated by a fragment not exhibiting the structure of the hinge and ears. The body is very flat, but the anterior ear is well-defined by a strong ridge, the umbonal slopes make an angle with each other of about 60°. The posterior lower angle is produced. Surface marked by obscure folds and striæ. Length along post-umbonal ridge 27 mm, along anterior umbonal ridge 17 mm. The considerable obliquity and flatness of the body are the obvious characters which are noted especially because the shell is found in a higher horizon than those previously mentioned.

Myalina michiganensis, Win?

(Cf. *M. swallovi.*)

(Plate IV, Fig. 6.)

The only difference between this species and M. swallovi of the coal-measures is in the greater size of the protuberance under the beak, but Meek says specifically: "This species (M. swallovi) varies somewhat in the size of the protuberance under the beaks; in some individuals it is well developed, and gives the shell much the form of *Modiola*; while in others it is smaller, so as to present more the appearance of a *Mytilus*." Perhaps it may be sufficient to indicate the probable genetic relations of these forms.

Modiola waverliensis, sp. n.

(Plate I, Fig. 9; Plate IV, Fig. 10; Plate VII, Fig. 29?)

(There has been no opportunity to consult the description of M. metella, H. so the possibility of agreement with this Chemung form is not excluded.)

Nearly like M. nevadensis, Wal., but less elongate. Transversely elongate, narrowly and uniformly rounded anteriorly, lower outline very gently curved, posterior end rather more broadly rounded than the anterior, the outline above diverging rather strongly to a point between the middle and the posterior third, where it meets the nearly straight hinge. Beak posterior, somewhat overhanging. Post umbonal slope quite well marked near the convex umbonal region, posterior part of shell rather flat. Length somewhat greater than twice the width.

A number of casts have been found in the freestone of the middle Waverly. Those specimens preserving the shell markings differ slightly from the cast first referred to and have fine concentric striæ. These may indicate a distinct species, but probably the apparent differences correspond to the different states of preservation.

Schizodus newarkensis, sp. n.

(Plate X, Fig. 1.)

Shell large, obliquely ovate, produced. Beak prominent, not projecting much beyond the hinge. Surface quite convex in the umbonal region, becoming flattened posteriorly. Lower margin a gentle curve, very oblique to the axis, anterior margin strongly convex, posterior margin a gentle curve meeting the lower line acutely. The post-umbonal region expanded, flat; anterior umbonal slope rather abrupt. Beaks anterior; surface marked by fine regular striæ. Our single specimen is very remarkable for the strong curvature of the surface below, opposite the beaks and flatness of the posterior ear. This may be due to oblique pressure as the opposite valve is crushed and displaced. Notwithstanding this the ovate form, large size and position serve to distinguish it. Length 62 mm; height 50 mm; convexity of both valves about 23 mm. Collection of W. F. Cooper. Highest layers 1 mile north of Newark.

Schizodus chemungensis, var? aequalis, n.

(Plate I, Fig. 25.)

Shell of rather large size, moderately convex; beaks projecting, rather high; length slightly greather than the height; form subquadrate, produced at the lower posterior angle; lower margin nearly uniformly convex, with a slight sinus in front of the posterior angle; posterior margin nearly straight and nearly parallel to the longitudinal axis of the shell; anterior margin strongly curved; anterior umbonal ridge rather inconspicuous, post-umbonal ridge prominent, in front of it a rather deep groove extending from the sinus of the margin toward the beak; post-umbonal slope rather steep, concave. Surface marked by numerous fine concentric striæ and coarser ridges. The right valve is most convex in our specimens. Height 42 mm; length 48 mm; (height 38 mm; length 42 mm.)

Freestone of middle Waverly at Granville, and 6 miles northwest. Collected by W. F. Cooper and C. L. Herrick.

We are convinced that the attempt to specifically discriminate the

Waverly from the Chemung form is futile. Hall states that the present species differs from S. chemungensis, var. quadrangularis in that the base is more broadly rounded and the anterior portion is more expanded below, giving the shell a more equilateral appearance. This is not appreciably so in our specimens, though considerable variation is seen. The close relation between the Chemung and Waverly is here obvious.

Plate IX, Fig. 20 represents a form still more like the Chemung species.

Schizodus cuneus, H.

(Plate V, Fig. 15.)

This little species is not rare in the freestone of middle Waverly, and may be easily recognized by its triangular form and small size.

Schizodus medinensis, Meek.

(Plate I, Fig. 16.)

The figured specimen is imperfect, but characteristic specimens are common in the freestone with the above.

Orthonota rectidorsalis, Win.

(Plate X, Fig. 1)

Shell of medium size, elongate, moderately convex. Hinge and ventral margins nearly straight and nearly parallel; beak sub-terminal; anterior margin gradually curved to above one half the height, then abruptly curved and slightly concave to the beak, which is very slightly elevated. Posterior margin angulate curved, making an angle of about 110° with the hinge line and passing by a more gentle flexture into the ventral border. The greatest thickness is about one-third from the anterior, the surface is evenly convex along a line passing toward the postero ventral angle. There is a rather deep groove passing parallel to the hinge from the beaks.

GENUS PROTHYRIS, Meek.

Prothyris meeki, Winchell.

This species occurs frequently in the shale below congl. II, but is by no means limited to that horizon. Its range and legitimate limits of variation have not been fully studied.

Sanguinolites (Goniophora) senilis, sp. n.

(Plate IX, Fig. 28.)

Cf. *Sanguinolites cuneatus*, DEKONINCK, and *Goniophora subrecta*, HALL.

Shell of rather large size, nearly rectangular, hinge and ventral margins nearly parallel, nearly straight and of nearly equal length. The anterior dorsal margin is nearly straight, making with the hinge an angle of about 120° or less, somewhat produced; posterior margin truncate at about a right angle and again obliquely truncate at the upper third (sometimes apparently curved rather than doubly truncate; in most specimens the postero inferior angle is more acute and produced than in the one figured, thus approaching G. subrecta, H.) Surface quite convex along the very prominent and rather acute postumbonal ridge, the greatest convexity being half way from the beak to the postero-ventral angle. On either side of the ridge the surface is plane for some distance, but anteriorly becomes concave, forming a broad sulcus passing from the middle of the ventral margin toward the beak; posteriorly the surface is flat for a considerable distance from the upper angle. The umbo is rather prominent. The surface is ornamented with very prominent, rather irregular, close, concentric lines, which are acutely angled upon the umbonal ridge. Length 60 mm; height 25 mm; beak distant from the anterior about 11 mm. Found only in shales four feet below conglomerate I, near Granville, O. In some specimens the resemblance to S. cuneatus, Dekon., approaches identity. From Goniophora subrecta it differs chiefly in the less elevated anterior extremity and slightly less produced infero-posterior angle. The relation is so obvious that we regard this shell as increasing the Devonian character of our division I.

Sanguinolites marshallensis, Win. ?

(Plate V, Fig. 11; Plate VII, Fig. 10.)

This shell bears some resemblance to S. transversus, Dk. (= Cypricardia rigida), but differs in the posterior margin. Shell sub-quadrate or sub-ellipsoidal, transversely elongate, with greatest convexity above the middle; hinge nearly straight and somewhat shorter than the shell, at its posterior termination being the greatest height of the shell; ventral margin shorter, somewhat concave or nearly straight, rapidly curving anteriorly to a point above the middle of the height, where it intersects the short, concave antero-dorsal margin; posterior margin doubly truncate, first below for two-thirds the height by a line inclined with the ventral about 130°, above by a shorter line making nearly the same angle with the cardinal line, giving the shell a nasute appearance behind. A prominent ridge passes from this projection toward the beaks and a similar one from the lower posterior angle, between which a decided sulcus is frequently observed, especially in large specimens. A less distinct sulcus extends from the middle of the lower margin towards the somewhat flattened, incurved beaks.

The following measurements illustrate the proportions: Length 22 mm, height 11 mm, convexity of single valve 3-4 mm; L. 33 mm, H. 15 mm; L. 28 mm, H. 14; L. 24 mm, H. 12.5 mm; L. 40 mm; H. 18 mm.

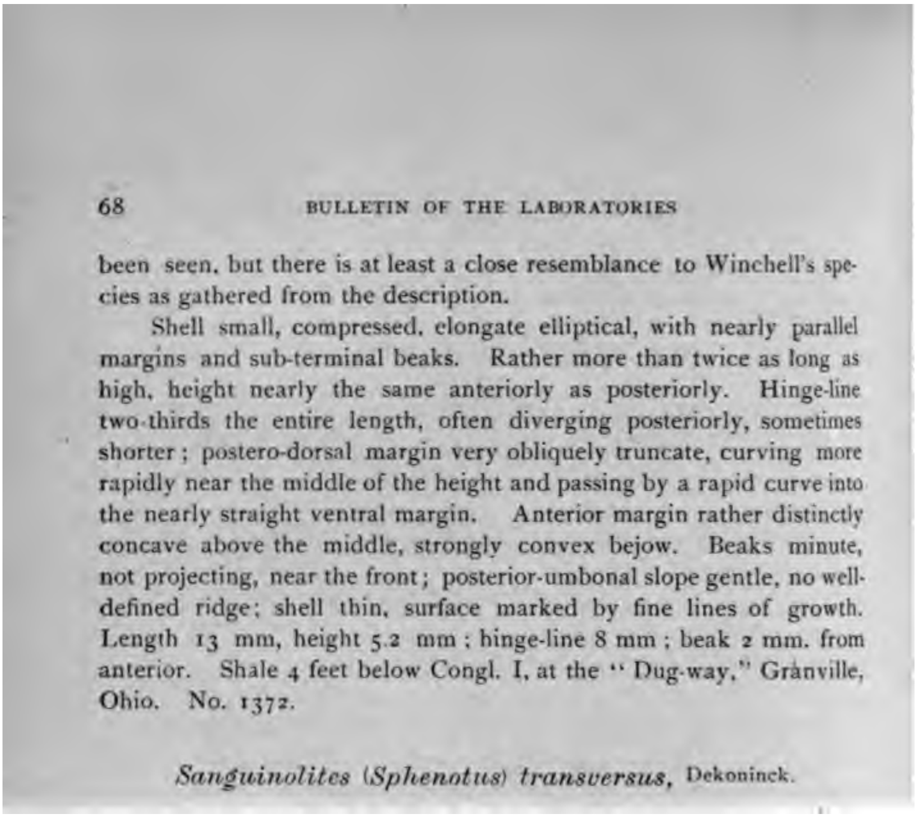
The identification as above was made at the suggestion of Prof. Winchell, as we were unable to harmonize the description with our specimens. This may be accounted for by the fact that the description was drawn from rather young forms, while ours have the peculiarities strongly marked.

Free-stone of middle Waverly, Granville, O.

Sanguinolites unioniformis, Win.

(Plate IX, Figs. 5, 7-9.)

Quite a number of very small shells, with rather constant characters from the basis of this description. The interior has in no case



been seen, but there is at least a close resemblance to Winchell's species as gathered from the description.

Shell small, compressed, elongate elliptical, with nearly parallel margins and sub-terminal beaks. Rather more than twice as long as high, height nearly the same anteriorly as posteriorly. Hinge-line two-thirds the entire length, often diverging posteriorly, sometimes shorter; postero-dorsal margin very obliquely truncate, curving more rapidly near the middle of the height and passing by a rapid curve into the nearly straight ventral margin. Anterior margin rather distinctly concave above the middle, strongly convex bejow. Beaks minute, not projecting, near the front; posterior-umbonal slope gentle, no well-defined ridge; shell thin, surface marked by fine lines of growth. Length 13 mm, height 5.2 mm; hinge-line 8 mm; beak 2 mm. from anterior. Shale 4 feet below Congl. I, at the "Dug-way," Grànville, Ohio. No. 1372.

Sanguinolites (Sphenotus) transversus, Dekoninck.

Sanguinolites (Cypricardia?) rigida. W. and W.

(Plate IX, Fig. 22.)

"Shell elongate, quadrangular, a little widest at the posterior end. Dorsal line straight, bounded by a rather broad escutcheon, which is more than half as long as the entire length of the shell. Anterior end truncate, prolonged near the basal margin; posterior extremity obliquely truncate; basal line straight, slightly emarginate, a little anterior to the middle, by a shallow sinus which crosses the shell from beak to base. Lunule large, deeply marked; beaks small, flattened on the umbones, and enrolled, situated anteriorly; umbonal ridge very prominent and angular, extending from the beak to the posterior-basal angle. A second, but less prominent ridge passes about midway between the first and dorsal line. Surface marked by sharp, closely-arranged lines, parallel to the margin, which are bent at right angles as they cross the umbonal ridge, and less abruptly at the minor ridge. Interior of shell with a sharp muscular ridge passing from the anterior side of the beaks, with a forward curvature, about 2/3 distance across the shell. Hinge-teeth absent, probably partially external ligament," This species is found rarely in the shales below the congl. I.

There is an *a priori* improbability that this species exists in Belgium as well as in America, but the identification of Dekoninck is positive.

Sanguinolites (*Sphenotus*) *contractus*, W. W.

(Plate XII, Fig. 4.)

A form identified with this Chemung species is found in shales at Moot's run, in the nodule layer, hence perhaps sixty feet below the horizon of S. rigidus=transversus. From that species it differs in being less robust, longer, less rigid, and in having less obtuse post inferior extremity.

The group of species here associated is a very intimate one and the specific distinctions may prove illusory.

Sanguinolites (*Sphenotus*) *flavius*, H ?

(Plate IX, Fig. 10.)

The resemblance between Sp. valvulus and Sp. flavius, as figured by Hall, is so close that one would be tempted to combine them unless full suites attest their autonomy.

Our specimens vary considerably, and in the surface characters resemble Sp. flavius, but often have more the outline of Sp. valvulus. The resemblance to small forms of *Sanguinolites naiadiformis* is great. From S. unioniformis with which they are associated they may be distinguished by the greater size and more produced posterior margin. Length 48 mm; width 18 mm.

Specimens found only in layer of shale a few feet below conglomerate I.

Sanguinolites (*Glossites*) *amygdalinus*, Win ?

This species is apparently represented in our collections, but not in specimens in suitable condition to describe. Its position is in the shale below congl. I.

Sanguinolites michiganensis, Win.

(Plate VIII, Fig. 10.)

This species has been a puzzle to me, but Prof. Winchell suggests that it is his S. michiganensis. The place and date of publication of this species are unknown to me. The resemblance is rather with Pleurophorus or Goniophora apparently. Found in the shale below conglomerate II, at Newark.

Sanguinolites aeolus, Meek.

(Plate VIII, Figs. 1, 11.)

This species is evidently causing some confusion. Walcott figures specimens under this name from the Eureka district, which are at least very doubtful. Our own specimens do not present entire agreement, but are not well preserved; they are derived from the shales below congl. II, with Allorisma winchelli. Meek asserts that the stratum referred to is upon the same horizon with that of the Cuyahoga shale. In as much as there is some reason to doubt this or to suspect that the Cuyahoga contains several horizons higher than this one, all identifications should be made conservatively. We suspect the identity of the specimens figured with the Cuyahoga species and reserve judgement.

Sanguinolites obliquus, Meek.

(Pal. O., Vol. II, Page 306.)

This shell is abundant one mile south of Newark, in the shale below congl. II, with Allorisma winchelli.

The following measurements indicate the typical proportions:

No.	Length.	Height.	Thicknes.	Height 1/3 from front.	Thickness 1/3 from front.	Proportions.
1	47	16	14	16	11	1-.34-.29
2	46	17	13	17	11	1-.36-.28
3	43	15	11	——	10	1-.34-.28
4	——	17	13	——	——	
5	——	21	17	——	——	
6	35	13	10	13	7	
7	50	17.5	16	——	——	
8	42	17	13	16	11	1-.38-.30

Sanguinolites naiadiformis, Win.

(Plate IV, Fig. 2.)

"Length 2½ the height; laterally flattened below the umbo; dorsal and ventral margins parallel or nearly so, the ventral sometimes with a broad, shallow sinus extending upward over the valves and vanishing near the umbo; a distinct umbonal ridge flattening out near the postero-ventral angle, at which place the outline presents a rounded angulation; postero-dorsal slope making with the dorsum an angle of 45°. Length 2¾ in; height 14-16; thickness ½ in."

The specimen figured is less typical than others from the freestone in that it lacks the ventral sinus. Length 75 mm; height 28 mm; convexity 16 mm.

A variety rather more common than the typical one has the umbonal ridge more prominent and the anterior ventral curve more convex. Several specimens measure about as follows: Length 75, 63, 66; height 28, 24, 26; convexity 20, 17, 18; length of lunule 15, 13, 13. This form extends into congl. II.

A small specimen from the shale below congl. I, closely resembles the above, but is smaller, measuring 36; height 17; convexity 9 (9): lunule 8. Plate IX, Fig. 3.

Allorisma (Sanguinolites) nobilis, Dekoninck.

(Plate X, Fig. 5.)

Very large, elongated, expanded and somewhat angulated posteriorly, nearly three times as long as high at the hinge, rather flat, greatest convexity near the middle of the valves.

Hinge line nearly straight and almost parallel with the very slightly curved lower margin; beak between 1-4 and 1-5 the distance from anterior margin, which is nearly straight and extends a little more than half the height of the shell, forming a rather acute angle; posterior margin nearly evenly curved or doubly sub-truncate. Surface marked by very strong, irregular, concentric ridges. The post-umbonal ridge is near the hinge and is very slightly elevated, below it are two still fainter ridges passing from the beak to the lower posterior angle and a point half way to the point where the umbonal ridge terminates. The single specimen seen is a little imperfect so the curvature of the beak could not be certainly seen. This shell is as large as *A. subcuneata*, which it greatly resembles in surface characters, but the presence of the Pleurophorus-like ridges and slightly angled posterior margin, and less convexity serve to readily distinguish it.

Near the top of free-stone at Granville, collected by W. F. Cooper.

This shell is apparently identical with S. nobilis, the only differences noted being the slightly greater anterior projection in our specimens, which are thus rather longer.

Allorisma cooperii, sp. n.

(Plate VI, Figs. 10.)

Shell of medium to large size, rather flat, expanded, and short. Very little more than twice as long as high; middle region evenly convex; beak not prominent, gently incurved, situated near the juncture of middle and anterior thirds. Hinge and lower margins nearly parallel, latter gently curved. Anterior margin rather long, slightly concave, meeting the lower margin below the middle at an acute produced angle. Posterior margin parabolic, nearly equally curved above and below. The height is nearly the same at the anterior and posterior thirds. The surface is marked with the usual concentric striæ, but whether granulated or not the condition of our specimens forbids conjecture. The post-umbonal ridge is close to the hinge line and not very prominent, while the antero-dorsal margin has no lunule.

Length 69 mm; height at beak 33 mm; distance of beak from anterior 20 mm.

This is a much shorter species than A. subcuneata, M., of the coal-measures, and has a longer anterior portion.

Two specimens from the upper layers of the free stone have been found with concurrent characters. Collected by W. F. Cooper, at Union Station, and by C. L. H., north of the "Dug-way."

Allorisma winchelli, Meek.

(Plate VIII, Figs. 2–4.)

Occurs in great abundance in a layer immediately below the 18-

inch conglomerate above the quarry rock in the south Newark quarry. It is here associated with *A. ventricosa*, *Edmondia* sp. *Sanguinolites obliquus*, and *Prothyrus meeki*.

The following measurements illustrate the range of variation at this place:

	Length.	Height.	Thickness.	Heigh a ⅓ rom post. end	Thickness a ⅓ from posterior.	Angle of antero-ventral margin.	Angle of antero-dorsal.	Anterior wing	Length to height to thickness.
1	51	23	22	23	18	42°	20°	5	1-.45-.43
2	48	23	21	23	17	40°	3°	4	1-.47-.43
3	47	24	22	25	20	40°	-°	3	1-.51-.46
4	53	23	20	22	14	38°	–	4	1-.43-.37
5	(52)	23	20	22	16	37°	13	4	
6	——	24	22	22	18				
7	(20)	12	10	7	7				
8	——	14	11	13	7.5				
9	47	23	22	24	17				
10	35	17	17	19	15				

Allorisma winchelli has once been found in shales above congl. I, showing that it was continuous throughout the period during which the free-stone was deposited. The animal lived buried in the mud, and is found with the valves in connection oblique to the lamination, and only in rocks which were originally mud of the shallow bays.

Allorisma ventricosa, Meek.

(Plates VIII, Fig. 6; Cf. Plate VII, Fig. 33.)

Our specimens differ considerably from Meek's description and also among themselves. The one figured expresses the extreme development of the tendency of the species, being shorter and more abruptly curved antero-ventrally and with more prominent beaks than others. A well marked ridge marking off the antero-umbonal slope is especially characteristic.

Length 34 (24); height 29 (19); thickness 18 (13); height at ⅓ from posterior 22 (15); thichness at same point 13 (10); anterior wing 5; angle of postero-ventral margin with hinge line about 56°. Measurements in parenthesis are of another specimen.

Allorisma convexa, sp. n.

(Plate XII, Fig. 27.)

Shell of medium size, quite tumid, with parallel margins and numerous fine striæ. Length nearly 2½ times the height; hinge and lower margins parallel and of equal length; lower margin abruptly rounded to the middle of the height, passing sharply into the concave antero-dorsal line; lunette well defined; posterior margin broadly rounded with slight angulation at the termini of two faint ridges between the post-umbonal ridge and the hinge; surface highest near the middle, flattened postero-dorsally; post umbonal ridge faint, the supra-umbonal ridges inconspicuous, but producing slight deviation in the numerous and regular concentric striæ. The cast shows a long cardinal groove. This shell is some respects a miniature of A. nobilis, but is much more convex. The radiating striæ characteristic of Allorisma may be detected upon the cast. From A. winchelli, which it exactly resembles in size, it may be distinguished by the parallel sides and the form of the posterior margin. From all other forms of this age it will readily be distinguished. Length 57 mm; height 23 mm; beak from the front 10 mm; convexity of both valves about 15 mm. Free stone layers of middle Waverly, 6 miles northwest of Granville. Collected by W. F. Cooper.

Macrodon ? ? triangularis, sp. n.

(Plate VIII, Fig. 8.)

A single right valve differs so from all associated forms that very little idea is afforded of its relations.

Shell thick, nuculiform, large; outline subtriangular, beaks rather prominent, somewhat incurved; hinge apparently flexed at nearly a right angle at the beak, anterior margin nearly straight, meeting the gently curved lower margin by an abrupt curve; posterior margin very short, forming an acute angle with the lower margin and a very obtuse one with the curved hinge line; post umbonal slope narrow, inclined to the general surface of the valve at nearly a right angle; surface marked by concentric striæ and folds; greatest convexity above the middle. Length 41 mm; height 35 mm. Free-stone of upper Waverly. The hinge characters are unknown.

Microdon reservatus, Hall.

(Plate IV, Fig. 14.)

This species is common in the free-stone of middle Waverly, but neither of our figures gives a typical form. Fig. 14 is abnormally elevated behind. Fig 4 of Plate X, is a small variety with beaks more central than usual. See Modiomorpha, below.

A typical specimen is sub-quadrangular, 1½ as long as high, flat, and finely marked concentrically. The lower margin is a very shallow elliptical curve; postero-dorsal slope slightly inclined, nearly plane; hinge line behind the beak nearly straight; posterior margin making with it an angle of about 120°, very slightly curved, anterior margin slightly concave forming an angle of nearly 140° with the hinge, antero-inferior projection rather abruptly rounded. Hinge in our casts showing only a shallow groove before and behind the beak. The generic reference is unsatisfactory.

Grammysia rhomboides, Meek.

(Plate VIII, Fig. 12 ?)

Typical specimens are frequent in the free-stone of middle Waverly. (Our figure is from an unusual form which may not represent this species.)

The relations of the associated form figured on Plate IV, Fig. 1, are unknown.

Gammysia hannibalensis, Shum.

This species is not very common in the free-stone of middle Waverly. Certain forms of Palæoneilo elliptica are are frequently mistaken for it. Fig. 13, of Plate IV, is apparently a fragment of this species.

Grammysia ventricosa, Meek.

Fine typical specimens are found in the Allorisma layer below conglomerate II, especially at Rushville. See Pal. O. Vol. II; also doubtfully identified from the free-stone below this horizon, at Newark and Granville.

Grammysia sp.

(Plate XII, Fig. 3,)

This small species has somewhat the aspect of an Edmondia and has not been carefully studied. From the nodules at Moot's run.

Modiomorpha hyalea. H. ?

(Plate X, Fig. 4.)

This identification is provisional. Our specimens are shorter and have more the aspect of a Grammysia. The species was derived from Granville, however, and the form here figured approaches it as nearly as any seen. Freestone of middle Waverly.

Edmondia depressa. H.

(Plate VIII, Fig. 5)

Shell thin, subquadrate, only moderately convex, umbones prominent, beaks incurved, approximate, near the front margin. Hinge line straight, equal to over one-third the entire length ; post umbonal ridge rather prominent, extending to postero-ventral angle ; post-umbonal slope bisected by an indistinct ridge extending from the umbo; pre-umbonal slope narrow ; posterior outline nearly straight, meeting the hinge line at an angle of about 111°, passing into the lower outline by an abrupt curve; lower line nearly parallel to the hinge, curving very rapidly to its junction with the rather straight front margin, which makes nearly a right angle with the hinge. Surface covered with fine concentric striæ and coarser folds parallel to the margin.

Our specimen gapes posteriorly and below, but probably the edges naturally apply all around. Greatest convexity upon the post umbonal ridge about one-fourth the distance from the beak to posterior angle. A shallow sinus extends from the umbo to the middle of the lower margin. Length 31 mm, height 22 mm, thickness 14 mm, beak about 7 m.m, from anterior margin, hinge 23 mm. Allorisma layer, below congl. II. at Newark and Rushville. Not having access to Prof. Hall's description. I am unable to make direct comparisons, but have no doubt that this is the species in question. The comparison with E. tapesiformis, Meek, reveals many differences, that species also seems to come from a different horizon.

Edmondia burlingtonensis, W. and W.

(Plate IX, Fig. 27, Fig. 17 (?); Plate IV, Fig. 18.)

Our species is doubtless the one generally identified with E. burlingtonensis and Prof. Winchell has made direct comparison of our forms with Iowa types and sustains the identification. There is, however, a wide range of variation in specimens on the same slab, the majority being almost like E. radiata, H., in form. The original description runs as follows:

" Shell of medium size, broadly subelliptical in outline, with regularly ventricose valves, breadth equal to three-fifths of the length. Beaks situated within the anterior third, strong, prominent, and incurved. Hinge-line and basal margin gently and equally curved; anterior and posterior extremities broadly and equally rounded. Surface marked by numerous strong, concentric undulations, parallel to the margin of the shell. In full-grown individuals there is a shallow, undefined sulcus, commencing near the centre of the shell. and reaching the border near the middle of the base." " Differs [from E. radiata] in having the posterior extremity narrower than the anterior, instead of much broader; and also in the concentric undulations."

After an examination of perhaps fifty specimens, all from the same bed within a few inches of each other (vertically), we observe the following nearly constant differences. The posterior part of the shell is higher than the anterior; sulcus well-defined; posterior margin much more broadly rounded than the anterior and obliquely sub-truncate above; finally, we are not sure the hinge structure is that of Edmondia.

To all appearance our specimens agree with the smaller form figured in Vol. V, Pal. N. Y., Part I, under the name Macrodon ovatus, though its relation to the typical larger form is less obvious. In some of our specimens the teeth of Macrodon were doubtfully observed.

Ctenodonta (Nucula) iowensis, W. and W.

(Plate I, Figs. 14, 17.)

A nuculoid shell resembling the one quoted is very common in the layer below congl. I.

Shell small, triangularly subovate, quite ventricose. Beaks about one-fourth or less from the anterior, prominent, acute, and incurved. Hinge abruptly bent at a little less than a right angle with about 10 posterior and 4–5 anterior teeth, anterior margin obliquely truncate; lower margin a nearly regular semi-elliptical curve. Surface marked by numerous plicæ, especially near the margin, where the epidermis is thickened. Length 10.5 mm, height 8 mm, thickness 6 mm. (?)

Ctenodonta (Nucula) stella, Win.

(Plate IX, Fig. 14.)

"Shell very small, elliptic-ovate, with sub-central beaks. Anterior cardinal slope arched, posterior nearly straight; extremities rather sharply rounded; ventral side semi-elliptic. Anterior hinge-plate with 17 minute, acute teeth; posterior with five. Beaks a little attenuated near the extremity, curved inwards and backwards. Shell thin, with delicate concentric striæ."

This species occurs with C. iowensis, in shales below congl. I.

Ctenodonta (Nucula) houghtoni, Stevens?

(Plate V, Fig. 17.)

A small species collected by Mr. Deming, in the shales over congl. II. is very like N. ventricosa, H.

Shell small, transversely sub-oval; height equal to 2/3 the length;

beaks rather prominent, incurved, situated over ¼ from the front margin; ventral margin rather evenly curved; posterior margin elliptical; anterior margin curved abruptly below, but passing by a nearly straight line to meet the produced hinge at nearly right angles. The escutcheon is well defined by a strong post-umbonal ridge; lunule well-marked. Greatest convexity near the middle; surface covered with fine, close lines of growth. Length 10 mm; height 7 mm, thickness 4.5 mm. The state of preservation forbids positive identification.

Nuculana (Leda) spatulata, sp. n.

(Plate IX, Fig. 11, (12?) Plate VII, Figs. 35.)

Shell elongate oval, broadly expanded anteriorly, acute behind; beaks small, slightly prominent, acute, about seven-twentieths the entire length from the anterior margin; hinge-line rather strongly concave; teeth (if present) small; anterior margin forming a bold, uniform curve, reaching nearly as high as the beaks, with its greatest anterior projection above or near the middle; lower outline gently convex, nearly attaining the hinge posteriorly, but separated from it by a short truncate posterior margin. Greatest convexity about one-third the height of shell from the beaks; umbonal ridge with a sudden, but gentle slope. The surface is marked by very numerous, fine lines of growth—about six occupying the space of 1 mm, in the shells measured. Length [1] 20, [2] 17, [3] 16.5; height [1] 9, [2] 7, [3] 8; distance from beak to front [1] 4, [2] 3, [3] 3; height of beak above longest transverse axis]1] 7,]2] 6, [3] 5. From Leda bellistriata of the coal measures, which it greatly resembles, it differs in being more expanded anteriorly, and having the most convex part of the anterior margin higher than the middle. Shales below congl. I. It is possible that this is Dr. Stevens' species, if so, however, its identification in the coal-measures must be regarded as erroneous.

Nuculana (Leda) similis, sp. n.

(Plate IV, Fig. 15.)

Shell large size, elongate, twice as long as high, rather flat; beak quite acute, rather prominent, curved anteriorly, about two-fifths the entire length from the front, hinge-line gently curved posteriorly, with about ten teeth; anterior margin a gentle curve with the focus in the lower margin in front of the middle; lower margin nearly straight behind, curving more rapidly as it approaches the front; posterior part of the shell narrow; the greatest elongation anteriorly is near the juncture of the lower and anterior margins. Judging from the cast the shell was very thick, no markings being preserved. Length 25; height 12; width 5-6 (?); beak to front 9; height of beak above longest axis 6 mm.

This is apparently the species identified by Prof. Hall [Pal. N, Y. Vol. V.] with N. pandoriformis, Stevens. The original description of Dr. Stevens seems, however, to forbid the reference.

Nuculana (*Leda*) *saccata*, Win.?

(Plate IX, Fig. 12.)

A single poor specimen from the same horizon as the above bears at least a superficial resemblance to the species quoted.

Palaeoneilo ellipticus, sp. n.

(= *Palæoneilo concentrica*, authors, not *cardinia concentrica*, Winchell.)

Shell moderately thick, probably gaping somewhat behind, strongly and evenly convex; outline nearly perfectly elliptical; hinge line extending in front of the beaks, convexly curved posteriorly and concave in front; about twelve oblique teeth in front and about twenty behind; beaks about one-third to three-fourths the length from the front margin, incurved to near the mediam plane; umbo moderately prominent, post-umbonal slope convex, parallel to the hinge-line; pre-umbonal slope very steep, the umbonal ridge being concave upwards; lower margin a uniform shallow curve; anterior and posterior outlines strongly and similarly curved. Surface of valves marked by few, distant, very prominent concentric ribs, the intervals being flat or concave, and finely striate. About twelve of the ribs are found on a shell of moderate size. Greatest convexity above the middle.

Length.	Height.	Be'k fr'm anterior.	Heig't at ⅓ from post.	Width.	Number of ribs.	Length to height.
23	12	7	10	8(?)	12	2–1
24	14		12		12	1.7–1
22	11	7	10	5–6(?)	11–12	2–1
16	8	5	7	—	10	2–1
18	10	5	9		10	1.8–1
21	12	6	10		12	1.7–1
11	6.5	3	5.5	4	6–8	1.6–1

Three varieties may be recognized by the character of the striations and these seem to be independent of size and may be worthy of specific distinction, though intermediate gradations connect them. One variety.

Var. plicatella

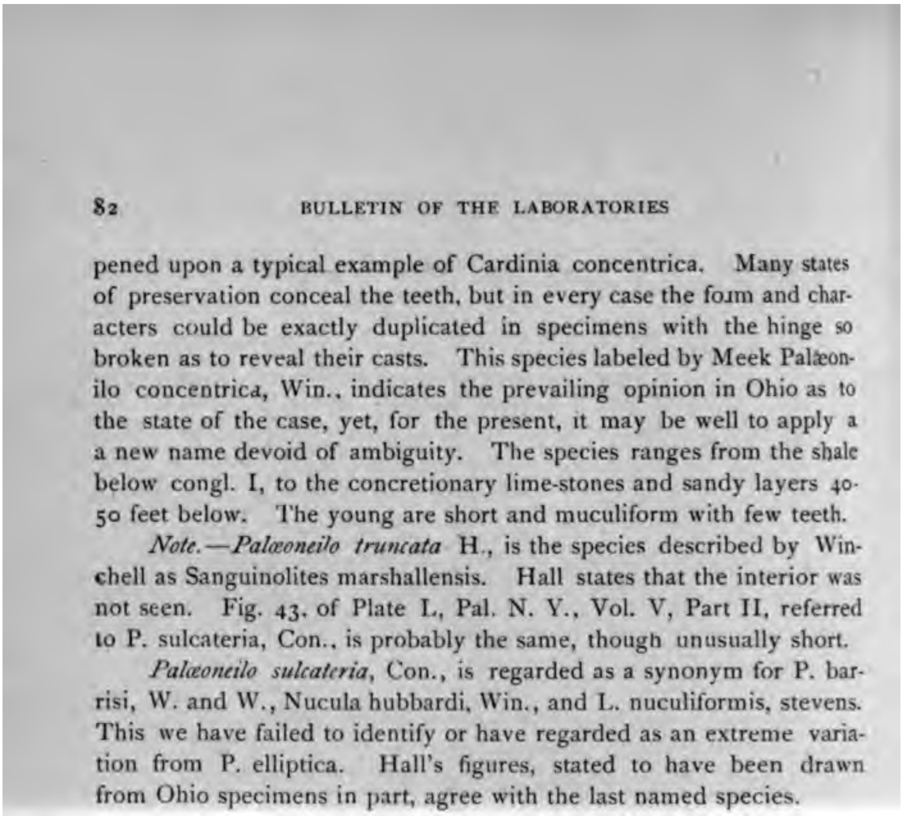
has coarse folds or ribs separated by wide intervals. A shell 13 mm. long and 8 mm. high, has only eight costæ. The youngest specimen seen is only 5 mm. long and 3.5 high and had but five or six costæ.

Var. elegantula

does not differ in proportions or hinge structure, but a shell 14 mm. long and 9 mm. high, has twenty costæ. A larger specimen 29 mm. long and 15 mm. high, has about 25 ribs.

Var. allorismiformis

has the beaks a little, farther forward and the intermediate striolations are nearly equal to the costæ, causing the shell to resemble allorisma. This species has given us much trouble. All the varieties herein described possess the hinge characters of Palæoneilo, which Cardina concentrica is said by Winchell, emphatically, not to possess. Nevertheless, specimens of the present species, which failed to exhibit the teeth, were regarded by Prof. Winchell as Cardinia concentrica. Either there is a species in Michigan exactly like ours, but without the teeth or in the examination of hundreds of specimens we have not hap-



pened upon a typical example of Cardinia concentrica. Many states of preservation conceal the teeth, but in every case the form and characters could be exactly duplicated in specimens with the hinge so broken as to reveal their casts. This species labeled by Meek Palæonilo concentrica, Win., indicates the prevailing opinion in Ohio as to the state of the case, yet, for the present, it may be well to apply a a new name devoid of ambiguity. The species ranges from the shale below congl. I, to the concretionary lime-stones and sandy layers 40-50 feet below. The young are short and muculiform with few teeth.

Note.—Palæoneilo truncata H., is the species described by Winchell as Sanguinolites marshallensis. Hall states that the interior was not seen. Fig. 43, of Plate L, Pal. N. Y., Vol. V, Part II, referred to P. sulcateria, Con., is probably the same, though unusually short.

Palæoneilo sulcateria, Con., is regarded as a synonym for P. barrisi, W. and W., Nucula hubbardi, Win., and L. nuculiformis, stevens. This we have failed to identify or have regarded as an extreme variation from P. elliptica. Hall's figures, stated to have been drawn from Ohio specimens in part, agree with the last named species.

Palaeoneilo attenuata, H.

(Plate IX, Fig. 25.)

Shell very thin, nacreous; valves slightly gaping behind, compressed, equal; outline subrectangular, produced posteriorly, hinge-line straight, extending scarcely forward of the beaks, with many minute teeth in two series, which are not in the same straight line at their union under the beaks, ligament apparently external; anterior margin strongly and evenly curved, extending nearly one-fourth the entire length forward of the beaks; lower margin very slightly convex, somewhat concave at a point about one-third the length from the posterior extremity; posterior margin acutish, the lower margin curving slowly upward until by an abrupt flexture it approaches the upper or hinge margin; greatest thickness about half the height, situated about one-third the distance from beak to front; a shallow depression passing from the slight sinus of the front margin toward but not to the beaks, dorsal part of shell with an abrupt descent to hinge, forming a very narrow but abrupt umbonal slope, generally also an umbonal ridge nearly parallel to the hinge; beaks small, approximate, extending above the hinge line, anterior umbonal slope steep, a short but well-defined lunule, surface marked only by fine, crowded, concentric striæ. Typical measurements as follows:

Length.	Height.	Height at ⅓ from posterior margin.	Thickness of both valves.	Distance of umbo from anterior.	H'ight to length.
(1) 25	11	8	5.5	7	1:2.27
(2) 24	10	8		5.5	1:2.40
(3) 39	16	12		10	1:2.43
(4) 18.5	8	6		5	1:2.31
(5) 26	11.5	8		7.5	1:2.26
(6) 24	10	8		6	1:2.40
(7) 29	13	9		8	1:2.23
(8) 27	12	9		6	1:2.25
(9) 29	12.5	11		7	1:2.32
(10) 17	8	6		5	1:2.12
(11) 12	6	4.5		3	1:2
(13) 12	5.5	4		3.5	1:1.118
(14) 10	5	3.5		3	1:2

Numbers 10–14 are small specimens with slightly different characters. The lower margin is straight and the proportional length is less, while the convexity of the surface is more uniform. All the specimens are derived from the shale below the congl. I, and this species is so abundant and constant that it forms a valuable index to this horizon. It is known from many localities. The form is quite like Nuculana, but Prof. Winchell says: "This has the aspect of Ctenodonta hubbardi, Win., but is too thin and rather too much attenuated behind. However, I have thin specimens from Holland, near Lake Michigan."

Arca ornata, sp. n.

(Plate IX, Fig. 18.)

Shell small; rather convex, beaks near the anterior third, acute posteriorly, hinge short. Rather convex near the beaks, which are prominent and incurved; lower line nearly straight, as long as the greatest length of shell; anterior margin slightly curved or nearly straight, intersecting lower line by a sudden curve; posterior outline obliquely truncate forming at the lower angle a regular acute curve; hinge short, inclined toward the posterior ventral angle; anterior umbonal ridge high, the slope making a strong angle with the surface of the valves; post-umbonal ridge near the hinge. Surface marked by rather distant concentric striæ and posteriorly by thread-like elevated radiating striæ. In general appearance this shell is very like *Macrodon delicatus* of the coal-measures, but differs from all species of Macrodon or Parallelodon in having the greatest length near the ventral line and the lower angles extended and acute. The markings distinguish it from any species of Arca of the Waverly. Length 18 mm; height nearly 8 mm; beak distant from anterior about 6 mm. Other broken specimens indicate that this species reaches a considerably greater size and that the entire surface, when preserved is covered by the fine but distinct radiating thread-like striæ.

GENUS GONOIDON, Gen. n.

(*Gonia*, an angle ; *odous*, a tooth.)

This name is proposed with some hesitation to receive a nuculiform shell seeming to differ in hinge structure from any genus of the Palæozoic era.

Shell equivalve, very unequilateral, gibbous, not gaping; resembling Palæoneilo, but the hinge is continuous, slightly flexed beneath the beaks, without true teeth, (?) but the hinge margin of both valves zig-zagged by sharp incisions into which corresponding projections of the opposite valve fit closely. The series of denticulations thus formed is continuous, but the size of the excisions diminishes before and behind the beaks. Posterior adductor scar nearly terminal.

Goniodon ohioensis, sp. n.

(Plate XII, Figs. 23, 24, 25.)

Shell closely resembling Palæoneilo; of medium size, very tumid, umbo prominent, incurved. The outline is oblong-elliptical, lower margin nearly straight, posterior extremity rather acutely rounded, anterior extremity short, abruptly rounded; hinge-line equal to nearly two-thirds the entire length, about twelve angulations behind the beak and six to eight in front; ligament apparently below the beaks, not disturbing the continuity of the series of angulations. The greatest convexity is near the umbo. Surface marked by fine regular concentric striæ. Length 14 mm; height 9.5 mm; thickness 8.5 mm; beaks 4 mm. from front.

This species was collected by W. F. Cooper, in the nodules and shale at the lowest exposure at Moot's run, 4 miles west of Granville. Although suggesting the genus Palæoneilo strongly we do not see how the hinge characters here described can permit this species to fall into any known genus.

Pholadella newberryi, H. and W.

(Plate III, Fig. 27; Plate IV, Fig. 4.)

Shell large, elongated, rather flat, more than twice as long as high, very short anteriorly, produced and rather narrow posteriorly. The lower margin is nearly straight, being rather abruptly curved anteriorly and more gradually posteriorly where it is produced to form an acute angle; posterior margin oblique, forming with the upper a very large angle; hing-line concave, shorter than the length of shell; the anterior margin short, nearly straight; umbones very prominent, beaks incurved over the hinge-line; post-umbonal ridge quite prominent, curved and becoming less distinct to its intersection with the lower posterior angle; post-umbonal slope quite abrupt near the beak, but becoming less so posteriorly; anterior to this ridge the surface is marked by numerous radiating thread-like striæ, which seem almost to lie upon rather than to form a part of the shell: these striæ abruptly cease at a point on the lower margin one-fifth the length from the anterior; shell otherwise covered by strong concentric lines and folds of growth. Prominent characters are the prominent and elevated umbones with the concave hinge line, oblique posterior margin and radiating striæ.

Length 90 mm; height at beak 35 mm; height posteriorly 30 mm; beak distant from anterior margin 13 mm.

Our specimens are apparently little distorted and are much (⅓) larger than those figured by Meek from Rushville. There can be no doubt of the identity, but our specimens show Meek's types to have been much more distorted than Meek's P. (Sedgwickia ?) obliqua proposed for the fragment figured. The species is apparently restricted to a rather narrow zone below the shale immediately underlying congl.

II, and above the free-stone proper or in its upper sandy layers. All our specimens being derived from Union Station and Granville.

GASTEROPODA.

Loxonema yandellana, H. (?)

(Plate VIII, Fig. 23.)

The fragment referred to this species agrees with the figures of the Spergen Hill form quite nearly, except in the presence of a well-marked sutural band, which may after all be due to the state of preservation. It is possible that the portion figured is only the upper part of the spire of a larger species. Most of our specimens do not preserve surface markings and can not be safely identified.

Cyclonema leavenworthana, Hall.?

(Plate I, Fig. 20)

This beautiful shell occurs in the upper part of the freestone near Granville, and differs in no respect from those described from the Spergen Hill limestone. From Murchisonia, some species of which it resembles closely, it differs in the absence of a peripheral band, the six volutions being marked only by thread-like revolving striæ. Our specimen is perhaps rather more slender than the types.

Pleurotomaria (Cyclonema?) strigillata, sp. n.

(Plate I, Fig. 10, Plate II, Fig. 25.)

Very similar to Cyclonema lyrata, Hall. Spire moderately elevated, composed of from two to four whorls, which are distinctly tricarinate below, but bicarinate above. The whorls increase rapidly, the body whorl being about one-fourth the entire height. The lower whorl is marked by rather distinct crowded incremental lines, which arch sharply backward in passing over the median carina, indicating that the aperture was probably notched. The two accessory carinæ are nearly as strong as the median one. The whorls are quite convex but are flat or even concave between the carinæ, being evenly rounded below to the apparently small umbilicus. Aperture unseen, apparently sub-circular. Height 16 mm; width 14 mm; height of first volution 9 mm, distance between the upper and median carinæ, 3 mm. The condition of our specimens makes it difficult to distinguish them from the Hamilton species quoted. Frequent in the upper parts of the freestone.

Since the above was written some very perfect specimens have been secured from Moot's run (see Plate XII, Fig. 39.) The species therefore may be regarded as ranging upwards into the freestone and not properly belonging there. From Cyclonema lyrata this form differs in lacking the revolving striæ on the lower surface of the whorls. Casts of the interior found in situ, show Fig. 15, of Plate I, to be such a condition of the present species.

Murchisonia quadricincta, Win. ?

(Plate II, Fig. 28.)

The numerous specimens are all casts in poor preservation, hence the reference is of the nature of a suggestion simply based on a general resemblance. Prof. Winchell informs me that the species has hitherto been only identified in Iowa.

Naticopsis ? sp. n.

(Plate XII, Fig. 37.)

Lack of time prevents a study of this interesting species. It is not certain that this is not a species of Strophostylus resembling S. varians, but is probably nearer to Naticopsis comperta.

Enomphalus latus, H. ?

(Cf. E. obtusus, H.)

(Plate XII, Fig. 26.)

Our only specimen is very imperfect, making it impossible to ascertain with certainty its characteristics. The upper surface of the volutions is concave, the outer margin is distinctly angled, and there is apparently an inner carina at the suture line. The under surface is evenly convex, widely umbilicate. The spire is slightly elevated, but is poorly preserved. The lines of growth are irregular. Our own opinion is that the present form is intermediate between E. obtusus and E. latus. The figure has been partly restored and must not be too implicitly trusted except for size and general configuration.

Free-stone layers of middle Waverly, 6 miles northwest of Granville. Collected by W. F. Cooper.

Euomphalus (spirorbis, H. ?)

(Plate II, Fig. 33.)

(Fig 33b is quite incorrect, the appearance of a lip is misleading and the spire is rather higher The specimen having been since removed from the matrix these errors have been detected.)

No opportunity has been afforded to compare with Hall's *E. spirorbis* hence our reference is based solely on memory. Shell small, elevated, closely coiled, umbilicate, having from four to five volutions. Volutions rather evenly convex, deeply excavated above for the superior volution, otherwise nearly circular in section Height nearly equal to the diameter of the largest volution.

Height of four volutions 7 mm; diameter of lower volution nearly 9 mm. Free-stone middle Waverly. This species reminds one of E. spergensis, var. planorbiformis, but the spire is higher.

Bellerophon cyrtolites, Hall.

(Plate VIII, Fig. 20; Plate IX, Fig. 29.)

Shell of medium size, laterally somewhat compressed, obtusely carinate; whorls very rapidly enlarging, slightly embracing, transverse section rhombic, sub cordate, broadest near the umbilicus; dorso-lateral slope flat or somewhat concave peripherally, strongly curved near umbilicus; umbilicus rather small. Aperture sub-cordate with a deep but not abrupt, acute notch.

Surface marked by numerous sharp geniculate or strongly curved transverse striæ meeting on the dorsum with an acute angle. Besides these, well-preserved specimens show less distinct revolving striæ upon the sides, especially near the umbilicus.

We have experienced much difficulty in identifying our Bellerophons. This species is poorly represented and very variable. The form which is referred with confidence to B. cyrtolites, is found in the shales below congl. I, and is about the size of the species quoted. The form is exactly as in the Illinois types. Very careful examination is necessary to discover the revolving lines; 13 is the maximum observed diameter.

A larger form occurs in the shales below congl. II, in which the concavity of the sides is more marked, as also the abruptness of the descent to the umbilicus. These are all in the form of casts preserving impressed lines of growth; 22 mm. is a common dimension for the greatest diameter. Above congl. II, in a blue friable shale, specimens more like the type are again found.

The second variety has been collected at Newark, Rushville and Granville, and has been discriminated as *B. cribristriatus.*

There are from 6 to 10 striæ in the space of one-tenth inch near the aperture. Dorso-ventral diameter of aperture perhaps 12-15 mm, transverse diameter 10-12.

Bellerophon galericulatus, Win.

(Plate IX, Fig. 32.)

"Shell small, globose, involute, carinate, ex-umbilicate, longitudinally striate, and deeply notched. Dorsum broadly and regularly rounded, without any evidences of a band except in approaching the aperture of adult shells, where a rather broad band, with ventrally concave incremental lines can be faintly traced, Aperture crescentic, not suddenly expanded, strongly auriculate, with the ears hanging detached from the inner whorl. Notch infundibuliform, deep and broad, obtuse, its sides reaching the tips of the auriculations. Umbilicus closed, scarcely indented. Dorsal and dorso lateral surface marked by about 28 longitudinal, sharply raised striæ, separated by much wider flutings and not perceptibly modified by dorsal band until within half of a whorl of the aperture of the adult shell, when the two middle striæ become slightly raised and enlarged and the entire set simultaneously die away. Between these striæ and the umbilical point similar striæ diverge spirally and irregular[ly] until intercepted by the former set or by each other. Cast smooth, perforately umbilicate. Average diameter of adult .47 (100); height of last whorl at the aperture .26 (55); height of aperture .18 (38); showing the inner whorl impressed into outer .08 (17); width of aperture .35 (74); depth of notch .22 (47); width of peripheral belt at notch .06 (13); separating distance between tip of auriculations and inner whorl .10 (21); number of striæ in 1-10 in. .10 (in young and old) largest seen diameter of .53." Bellerophon galericulatus is quite common in the shales four feet below congl. I.

Bellerophon, sp?

(Plate XII, Fig. 36.)

A species with decided Devonian affinities is illustrated from the nodules at Moot's run. It is sufficiently distinct from any of the above species, but we have no time to study its relations with Devonian species.

Bellerophon perelegans, M. and W. ?

(Plate IX, Fig. 30.)

"Shell small, subglobose; umbilicus small, aperture transverse, reniform. Back and sides marked by fine, sharply elevated revolving lines, which are about equal to the spaces between them, finer and more closely arranged in the middle than on the sides of the shell. Dorsum marked by a narrow, elevated, revolving band, bounded on either side by a shallow depression. The revolving lines on the band are much finer than those on the body of the shell. Very fine striæ of growth cross the revolving striæ, giving a finely cancellated appearance to the surface. Margin of the peristome nearly straight or with a gentle backward curvature to the shallow central notch."

Our knowledge of this species is confined to fragments of several individuals with tolerably constant characters. The band, except near the peristome, is rather concave, the transverse striæ are more regular and often more conspicuous than the revolving, otherwise the agreement is close. With B. galericulatus, 4 feet below congl. I.

GENUS PLATYCERAS.

Of this genus six species are reported by Prof. Winchell from Ohio, viz: P. bivolve, P. haliotoides, P. hertzeri, P. paralium, P. romerium, and P. subplicatum.

Platyceras hertzeri, Win.

(Plate II, Fig. 24, and Plate V, Fig. 8.)

The difficulty of distinguishing the variable species of Platyceras rather increases than diminishes with the accumulation of specimens. The present species, which may be recognized by its moderately large size and irregularly plicate, nodulose surface, and compressed form extends from the free-stone into conglomerate II. There is generally a poorly defined carina near the outer margin as well as irregular transverse plications. From P. haliotoides it is distinguished by the less closely coiled spire.

Platyceras haliotoides, M. and W.

(Plate II, Fig. 23.)

Our figure illustrates a small and not particularly characteristic specimen. Many specimens agree fully with the Illinois types, while others pass toward P. hertzeri. The upper surface is convex, with only a very faint revolving groove or none, the outer surface being narrowly rounded, the aperture very oblique. From P. hertzeri it may also be distinguished by the closely incoiled spire. With the last.

Platyceras bivolve, M. and W. ?

A single specimen is doubtfully identified with this species.

Quite small, very ventricose, composed of (less than) two closely coiled rounded volutions; spire not elevated; inner whorl minute, outer whorl very rapidly expanding, ventricose, expanding especially downward; section of volution broadly ovate, broadest externally; aperture with a faint sinus on the upper and lower external aspects. With the last.

Platyceras sp. Cf. *P. paralium,* M. and W.

(Plate I, Fig. 23, (Fig. 22?)

We have a few specimens resembling *P. paralium*, which differ from the above in having a well-defined revolving ridge and groove of the upper surface. The spire is minute and the aperture not very oblique. With the above.

Dentalium granvillensis, sp. n.

Closely related with *grandævum*, Win.

Shell large, straight, oval in section; tapering about .078 in one inch, marked except near the aperture by fine thread-like striæ which cross the surface nearly at right angles and are more or less regular. Casts are nearly perfectly smooth. This species most nearly resembles D. canna, but is always oval in section. The striæ nearly seem to cross the shell at right angles and on well-preserved specimens are strong and elevated. No evidences of longitudinal markings were seen. The length may have exceeded 8 cm. The longest fragment measures 49 mm. The longer diameter at the apertural end is 9 mm, at the apical 5 mm; another 50 mm. long measures aperturally 10 mm, apically 6 mm, or about 8 mm. contraction per cm. D. grandævum is said to expand more rapidly, but may not prove distinct.

Free stone at Granville.

Goniatites lyoni, M. and W.

Fragments apparently indistinguishable from this species were collected in the free-stone of middle Waverly at Granville. The types were from the Goniatite bed of the Kinderhook group, a zone certainly embraced within the limits of our Waverly.

Another and apparently distinct species is characteristic of the upper layers of division III. See Plate VII, Fig. 27.

Conularia newberryi, Winchell.

(Plate VI, Fig. 13; Plate VIII, Fig. 9; Plate II, Fig. 18?)

This species as quoted by Meek (O. Pal. Vol. II, p. 316), was wrongly attributed to Hall. It was described by Winchell. [Proc. American Philos. Soc., July, 1865, p. 130.] The original description was written from a small fragment and gives an imperfect idea of the species as a description of a specimen merely always does.

"Shell very small, in the form of a quadrangular pyramid. The pyramid is inclined over one of the angles. Angles of the pyramid slightly rounded and marked by a shallow groove running longitudinally. Each side is marked by sharp raised transverse lines, which instead of running directly across, are angulated in the middle, so that at this point they are nearer the base of the shell by a distance equal to once and a half the distance between two lines. The distance between the lines increases from above downwards and is everywhere equal to about one ninth of the width of the side. These transverse lines have the appearance of the projecting edges of septa, and are continuous from the middle of one of the shorter sides of the pyramid around to the same point, though the ends do not join, but are alternate in position. The sides of the pyramid are inclined at an angle of about 30°." The fragment, about one-half inch long, had a basal diameter of .17. Cuyahoga Falls, O., in water limestone, below the conglomerate Prof. Winchell reidentifies this species from bed 4. Sciotoville, O. [Proc. Am. Philos. Soc., Vol. XII, Jan. 4, 1870, p. 258.] "The species appears to have been at least three or four inches in length; the septa range from 17-44 to the inch; it bears a V-shaped furrow along each of the angles, within this furrow the septa are deflected abruptly toward the base of the shell, so that they meet from opposite sides about at a right angle; the septa also sweep toward the base with a gentle curve in their extension across the side of the pyramid, by which their centres are about two intervals lower than the portion of the ridge which bounds the angular furrow. The septa are ornamented along their margins by delicate granulations."

Mr. Meek's figure and description, being drawn from a very imperfect specimen, add nothing to the above and hardly serve to identify the species. The specimen figured upon Plate VI, is from the lowest horizon, coming from the same bed as Spirifer marionensis. It is remarkable for the slight angle at which the sides converge toward the apex and the strictly quadrangular section. One face measures 15 mm. transversely, the other 12 mm. at the aperture, which shows the presence of deep sinus at the angles, while the faces from the inclined flaps long since indicated as a character of the genus. The angle made by the sides is less than 10°. There are twelve transverse striæ in one centimeter or about 15 in half an inch near the aperture. These striæ exhibit distinct pearling upon their summits, the minute pustules being rather distant from each other. The length may have been three or four inches unless more rapidly tapering above.

Other specimens from the shale below congl. I, are apparently identical. In the free stone the same species appears, though our specimens indicate a more obtuse spire and are not in a condition to exhibit the ornamentation. In the shale below congl. II, specimens of larger size but similar characters occur. Finally, small specimens from the Cuyahoga shale are decidedly of the same type Neither do we know how to distinguish the form found in the lower shales of the coal-measures, though the crenulations have not been seen. None of these show any traces of the barred longitudinal markings of *C. byblis*, W., *C. missouriensis*, as identified by Meek and Worthen, has coarser and more distant striæ.

Conularia micronema, Meek.

(Plate II, Fig. 19.)

"Shell elongate-pyramidal, with the sides equally diverging from the apex with an angle of about sixteen degrees ; lateral surfaces nearly flat, and without any mesial furrow [sic] but sometimes showing a very faint, slender mesial ridge, which becomes nearly or quite obsolete toward the smaller end ; each of the four angles a little rounded and provided with a shallow, moderately distinct longitudinal furrow. Surface with numerous extremely small, closely crowded transverse striæ, of very nearly the same size on all parts of the shell; striæ gently arching forward as they cross the side, and scarcely interrupted at the little mesial longitudinal ridge, minutely crenate, and separated by extremely slender linear furrows, numbering fifteen in the space of one-tenth of an inch on all parts of the surface; crenulations of striæ twelve to fifteen in one-tenth inch."

Length apparently about 3 inches.

Compare *O. subcarbonaria*, M. and W.

Conularia byblis, White.

Conularia byblis, WHITE, Proc. Bost. Soc. N. H., Vol. IX, p. 22. "Shell large, in the shape of a truncated pyramid, length twice (?) the width at the base, apex broadly rounded, smooth, sides depressed, convex; grooves at the angles narrow, a faint longitudinal depression, along the middle of each side; transverse ridges narrow, distinctly raised, forty-five or fifty to the inch, but slightly curved in passing from the salient angles to the faint central depression, at which they meet at an obtuse angle and cross with slight interruption; sometimes, however, they alternate for a short distance and then cross continuously as before. Spaces between the ridges finely crenulate. Chemung beds at Burlington, Ia." Winchell states further that there are small granulations ranged in a line along the crests of the ridges, 60–75 of which occupy the space of an inch. He refers the "crenulations between the ridges" to transverse bars developed between the ridges in worn specimens. The septa range from 56–128 to the inch. The septa-margins trend toward the base, but they are more nearly straight from angle to centre than C. newberryi. Winchell's specimens come from dark bituminous shales. Hickman Co., Tenn.

This form has not been encountered in Licking county, but is quoted for reference.

Stictopora striata, Hall.

(Plate XII, Fig. 40.)

Beautifully preserved and abundant specimens of a Stictopora are found in the nodules at Moot's run, and these can not be distinguished with the time at disposal from the Hamilton species quoted. Several other species associated in this horizon await a better opportunity. We reproduce part of Prof. Hall's description. "Zoarium consisting of a flattened, dichotomously branching frond arising from a spreading base. Branches 3-4 mm; margins sometimes parallel, at others slightly diverging, the greatest increase in width in a length of 15 mm. being 1 mm; non-celluliferous marginal space narrow, width .15 mm, not flat: transverse section regularly convex on the two sides, greatest thickness .50 mm; bifurcations comparatively distant, branches diverging at an angle of 60° or more. Cells tubular, for the greater portion of length very oblique, often nearly parallel to the mesotheca, then turning and opening obliquely to the surface, on the narrower portion of the branches often recumbent for nearly the entire length. * * *. Cell apertures very broadly oval, often circular, sometimes pustuliform, disposed in somewhat irregular longitudinal rows, but the rows being very close together and the apertures being separated by more than twice their diameter, the arrangement is indistinct; they sometimes alternate and form oblique transverse rows and often irregular, direct transverse rows. Marginal apertures very little if at all larger than the others. Peristomes moderately thick, strongly elevated, smooth; interapertural and marginal space striated, striæ short, tortuous, interrupted."

While some doubt may still exist as to the identity of our species with the above, its Devonian affinity is obvious.

ADDENDA.

[*To Page* 65.]

Schizodus [Protoschizodus] palaeoneiliformis, sp. n.

(Plate XII, Fig. 44.)

Six specimens found since the above was printed present concordant characters.

Of small size, sub-nuculiform, produced behind, equivalve, length to height as 23 to 15. Beaks less than one-third the length from the anterior; hinge somewhat over half to nearly two-thirds the total length; anterior margin short, broadly rounded, passing gently into the very slightly and uniformly curving lower margin, which meets the acute posterior angle at a point below half the height; posterior margin slightly concave, inclined to the longitudinal axis about 40°, making an angle of about 150° with the declined hinge margin. Greatest convexity of valves near the beak, from which a strong post-umbonal ridge passes to the posterior angle, above which the surface is concave; entire surface marked by fine thread-like, closely arranged striæ. Although our specimens are rather strongly produced and the interior could not be seen there is little doubt of the generic reference.

Length 24 mm. (19–17); height 15 mm. (11–10.) Freestone of middle Wavery, Union Station. W. F. Cooper collector.

This species may be compared with *Sch. nuculiformis* or *Sch. obscurus*, Dekoninck.

Conocardium pulchellum, White and Whitfield.

(Plate I, Fig. 12; Plate VII, Fig. 39, Fig. 40?)

"Shell small, general form triangular, with ventricose valves. Hinge line straight, the length equal to that of the posterior slope. Anterior end cuneate; posterior end obliquely truncate. Basal line gently arcuate, widely gaping near the anterior extremity; hiatus elongate ovate, distinctly crenulate on the inner border. Beaks minute, incurved, situated posteriorly; umbonal slope rounded, posterior space concave; siphonal tube small. Entire surface marked by distinct, diverging radii, those of the posterior space a trifle finer than those of the body of the shell; also by very fine concentric striæ. Greatest length .4 inch."

Identified from Newark by Winchell. (Am. Philos. Soc. Vol. XII, p. 256.)

It seems to be common at Granville, also, in the free stone of middle Waverly.

Another species is represented, but is known only from distorted specimens. (See Fig. 41, Plate VII.)

	OHIO.					
NAME.	I	II	III	ILL.	ELSEWH'RE.	REMARKS.
Phillipsia meramecensis			o		Missouri.	Archimedes.
Phillipsia shumardi		o			"	Chouteau.
Phillipsia præcursor	o					sp. n.
Pleurodictyum problematicum		o		o	Europe.	Devonian.
Orbiculoidea sp.		o				
Crania hamiltoniæ	o					Devonian.
Productus nebrascensis		o	o			Coal-meas. sp.
Productus semireticulatus		o	o			"
Productus arcuatus			o		Iowa.	
Productus burlingtonensis			o		"	Sub-carb.
Productus shumardianus	o				"	Devonian.
Productus concentricus	o				Michigan.	"
Productus lachrymosus	o				New York.	"
Productus speciosus	o				"	"
Productus gracilis	o			o	Michigan.	"
Chonetes logani	o		o	o		
Chonetes illinoisensis		o	o	o		
Chonetes scitula	o	?				
Chonetes tumidus	o					Devonian affinity.
Chonetes pulchella		o			Michigan.	
Hemipronites crenistria	o	o	o		∞	
Orthis vanuxemi, var.		o				
Rhynchonella contracta	o	o			New York	Devonian.
Rhynchonella subcuneata?	o					"
Rhynchonella sageriana	o					
Rhynchonella sappho		o	o		New York.	Devonian.
Rhynchonella marshallensis		o			Michigan.	
Atrypa reticularis		o	?		∞	Devonian.
Syringothyris cuspidatus		o			∞	
Spirifer marionensis	o				Missouri.	
Spirifer striatiformis			o			
Spirifer biplicatus		?				
Spirifer winchelli		o				sp. n.
Spirifer varicosta ?						
Spirifer hirtus		o				
Cyrtina sp.	o					
Spiriferina solidirostris		o				
Spiriferina depressa		o				sp. n.
Cryptonella eudora		o			New York.	
Centronella julia		o			Michigan.	
Athyris ohioensis		o				
Athyris lamellosa	o					
Aviculopecten perelongatus		o				sp. n.
Aviculopecten grandvillensis		o	?			sp. n.
Aviculopecten sp. (p. 51.)			o			
Aviculopecten cooperi	o					sp. n.
Aviculopecten oweni ?		o				
Crenipecten newarkensis		o				
Crenipecten subcardiformis	o					sp. n.
Crenipecten senilis		?				sp. n.
Lyriopecten ? cancellatus	o					sp. n.
Limatulina ? ohioensis			o			sp. n.
Streblopteria media	o					sp. n.
Streblopteria squama	o					sp. n,

NAME.	OHIO. I	OHIO. II	OHIO. III	ILL.	ELSEWH'RE.	REMARKS.
Streblopteria gracilis		o				sp. n.
Pernopecten shumardiana	o					
Pterinopecten cariniferus	o					sp. n.
Pteronites obliquus	o					sp. n.
Leptodesma scutella	o					sp. n.
Posidonomya fragilis	o					sp. n.
Promacra truncata	o					sp. n.
Leiopteria ortoni	o					sp. n.
Leiopteria halli		o				sp. n.
Leiopteria sp	o					
Leiopteria sp		o				
Myalina michiganensis		o			Michigan,	
Modiola waverlyensis		o				sp. n.
Schizodus newarkensis			o			sp. n.
Schizodus chemungensis		o			New York.	
Schizodus cuneus		o				
Schizodus medinaensis		o				
Schizodus palæoneiliformis		o				sp. n.
Orthonota rectidorsalis	o				Michigan.	
Prothyris meeki		o				
Sanguinolites senilis	o					sp. n.
Sanguinolites marshallensis		o			Michigan.	
Sanguinolites unioniformis	o				"	
Sanguinolites transversus	o				o	
Sanguinolites contractus	o				o	
Sanguinolites flavius	o					
Sanguinolites amygdalinus	o				Michigan.	
Sanguinolites michiganensis		o			"	
Sanguinolites aeolus		o				
Sanguinolites obliquus		o				
Sanguinolites naiadiformis	o	o			Michigan.	
Allorisma nobilis		o			Belgium.	
Allorisma cooperi		o				sp. n.
Allorisma winchelli		o				
Allorisma ventricosa		o				
Allorisma convexa		o				sp. n.
Macrodon ? triangularis		o				sp. n.
Microdon reservatus		o				
Grammysia rhomboides		o				
Grammysia hannibalensis		o				
Grammysia ventricosa		o				
Grammysia ? sp	o					
Modiomorpha hyalea		o				
Edmondia depressa		o				
Edmondia burlingtonensis	o					
Ctenodonta iowensis	o				Iowa.	
Ctenodonta stella	o				Michigan.	
Ctenodonta houghtoni ?		o				
Nuculana spatulata	o					sp. n.
Nuculana similis	o					sp. n.
Nuculana saccata	o				Michigan.	
Palaeoneilo elliptica	o				?	sp. n.
Palaeoneilo plicatella	o					sp. n.
Palaeoneilo elegantula	o					sp. n.

NAME.	OHIO. I	OHIO. II	OHIO. III	ILL.	ELSEWH'RE.	REMARKS.
Palaeoneilo allorismiformis	o					
Palaeoneilo attenuata	o					
Arca ornata	o					sp n.
Goniodon ohioensis	o					sp. n.
Pholadella newberryi		o			Michigan.	
Conocardium pulchellum		o				
Loxonema yandellana		o		o		
Cyclonema leavenworthana		o		o	Iowa.	
Cyclonema strigillata	o					sp. n.
Murchisonia quadricincta		o				
Naticopsis sp	o					
Euomphalus latus		o				
Euomphalus spirorbis		o				
Bellerophon cyrtolites	o	o		o		
Bellerophon galericulatus	o					
Bellerophon sp	o					
Bellerophon perelegans	o					
Platyceras hertzeri		o				
Platyceras haliotoides						
Platyceras bivolve		o				
Platyceras paralium ?		o				
Dentalium granvillensis		o				sp. n.
Goniatites lyoni		o				
Goniatites			o			
Conularia newberryi	o	o	o			
Conularia micronema		o				
Conularia byblis		?				
Stictopora striata	o					Devonian.

If we examine the above table candidly we discover at once that our suspicion that the Waverly is not homogeneous is abundantly substantiated, and not less noticeable is the difference in habitus between these assemblages. The lines chosen as the outlines of our divisions were selected because they mark shore deposits and thus are transition zones, as the deposits of a progressing or retreating littoral zone must always be with regard to the sea basin deposits formed before and after the fluctuation in level producing the movement. Certainly no other lines will prove more convenient in Licking county, though all such zones may be arbitrary as regards other areas. Now in number I, extending say 100 feet below congl. I, the fauna, as so far worked, presents about the following relations: Species of carboniferous habit, 2 or 3; species with decidedly Devonian habit (often closely related to Hamilton species), 25; species not found outside this zone or if so in horizons still under discussion, 30. In No II, embracing all between congl. I and II, species with carboniferous habit, possibly 9; species with Devonian affinities (often Chemung species) 12; species which are limited to this horizon or horizons still debated, 45. The division III, requires more study, but at least 7 species with carboniferous habit and 10 with no special bearing are unmixed with a species of Devonian alliances so far as known, except near the base. The evidence here is, it is true, chiefly negative. These conclusions have been reached on as conservative a basis as possible. If there is any error it is rather in favor of the carboniferous tincture in the two lower members.

The tentative conclusions now held are, therefore, as follows: The Waverly group of Ohio is a composite assemblage of lithologically constant character. The lower portion of it is, chiefly composed of greyish, yellowish, and greenish, arenaceous shales, with local grits and nodulary masses of limestone, and occasionally near the base intercalated layers of bituminous shale. This series is faunally nearly distinct in Central Ohio and should be regarded not only as Devonian, but as containing persistent elements of the Hamilton types in connection with Portage and Chemung forms. However, it is believed that geographical variation must be called in very largely to explain the specific divergencies, while generic resemblances remain perfectly obvious.

Our division II, although so relatively small, was evidently a transition period. Most of the strata may have been deposited while the Catskill was forming at the east, but the fauna was essentially of Chemung character. Nevertheless the connection in Ohio was much more direct with areas where already carboniferous types were appearing and a more or less marked admixture was the result. Conglomerate II marks a slight oscillatory wave passing perhaps from north to south, resulting first in mud flats in which burrowing mollusks thrived, later in shorelines kept supplied with pebbles by re-invigorated rivers. When the sea next returned it was with its freight of carboniferous forms, but the old Chemung species had chiefly perished during the slight oscillation. Comparatively few deep-sea forms accommodated themselves to the littoral conditions for a time, but such as did are related with Burlington or Keokuk species, which formations were then accumulating to the westward. It is not difficult to conceive that conditions might exist in Ohio, which would considerably alter specifically, a fauna pretty closely concordant generically with the Chemung in New York. In our second division a number of species are specifically identical with those in New York. Yet we prefer to believe that the freestones of the middle Waverly in Ohio, lie chronologically somewhat above the Chemung and include the Catskill epoch. The upper member doubtless includes equivalents of the base of the Burlington sandstone. The Cuyahoga shale presents a problem still difficult of solution, but we suspect a surprise awaits geologists when it is carefully studied. It is probable that the black or Ohio shale lies below the horizon of the typical Genesee.

In conclusion, it seems that no better evidence were necessary to convince one of the continuity of animal existence than that here afforded. Not only do rigid lines of stratigraphy break down, but hard and fast specific distinctions are obliterated and we begin to see how the retreating and advancing and ever-varying sea flung the shuttles back and forth, weaving the intricate pattern of historic geology without ever breaking the thread of life or resetting the web. But every new struggle brought out hitherto undeveloped possibilities in life and, instead of perishing, life ever came off victor by virtue of implanted aspiration and the environment of conscious force—God.

NOTE:—After the first portion of this paper was in type, accumulated observations place the stratigraphy of the lower portion of the series on a more definite footing, showing the nodule layer so often mentioned to lie about 40 feet below the horizon of Leiopteria ortoni and Crenipecten subcardiformis, and hence between 60 and 80 feet below the congl. I, at Union Station, south of Granville.

PLATE I.

Fig 1. *Spirifer winchelli*, sp. n., small dorsal valve.
Fig. 2. *Spirifer*, sp?
Fig. 3. *Spirifer marionensis?*
Fig. 4. *Chonetes gracilis?*
Fig. 5. *?*
Fig. 6. *Spirifer striatiformis*, var?
Fig. 7. *Syringothyris cuspidatus*, var?
Fig. 8 *Spiriferina solidirostris?*
Fig. 9. *Modiola waverlyensis*, sp. n.
Fig. 10. *Pleurotomaria strigillata*, sp. n.
Fig. 11. *?*
Fig. 12. *Conocardium pulchellum.*
Fig. 13, *Streblopteria media*, sp. n.
Fig. 14. *Ctenodonta iowensis.*
Fig. 15. Internal cast of same species as Fig. 10.

Fig. 16. *Schizodus medinaensis*, imperfect cast.
Fig. 17. *Ctenodonta iowensis.*
Fig. 18. *Aviculopecten winchelli*, right valve.
Fig. 19. *Streblopteria media* sp. n.
Fig. 20. *Cyclonema leavenworthana* (?)
Fig. 21. *Bellerophon cyrtolites*, compressed specimen.
Fig 22. *Platyceras* sp?
Fig. 23. *Platyceras paralium.*
Fig. 24. *Productus nebrascensis.*
Fig. 25. *Schizodus chemungensis.*
Fig. 26. *Productus semireticulatus.*
Fig. 27. Plant stem.
Fig. 28. Crinoidal plate.

PLATE II.

Figs. 1, 2, 3. *Spirigera ohioensis?*
Fig. 4. *Centronella* sp?
Fig. 5. *Centronella julia.*
Fig. 9. *Schizoaus medinaensis*, very poor cast.
Fig. 7. *Athyris lamellosa.*
Fig. 8. *Centronella* sp?
Figs. 9 11. *Spiriferina solidirostris.*
Figs. 12, 13. *Rhetzia* sp.
Fig. 14. *?*
Fig. 15. *Rhynchonella sageriana* (= var. of R. sappho?)
Fig. 16. *Spirifer winchelli*, sp. n.
Fig. 17. *Syringothyris cuspidatus.*
Fig. 18. *Conularia.*
Fig. 19. *Conularia micronema*
Fig. 20. *Limatulina ? ohioensis*, sp. n.
Fig. 21. *Chonetes tumida.*
Fig. 22. *Phillipsia shumardi.*
Fig. 23. *Platyceras*, sp.
Fig. 24. *Platyceras*, sp.
Fig. 25. *Pleurotomaria strigillata*, sp. n.
Fig 26. *Nautilus ?* sp.
Fig. 27. *Bellerophon cyrtolites.*
Fig. 28. *Murchisonia.*
Fig. 29. *Bellerophon cyrtolites.*
Fig. 30. *Bellerophon* sp.
Fig. 31. Plant impression.
Fig. 33. *Euomphalus spirorbis?*
Fig. 34. *Bellerophon galericulatus.*

PLATE III.

Fig 1. *Crenipecten senilis*, sp. n , left valve.
Fig. 2. *Spirifer hirtus*, M. and W. ?
Fig. 3. *Platyceras*, sp.
Fig. 4. *Streblopteria media*, small rigbt valve.
Fig. 5. *Aviculopecten* (cf. *Oweni.*)
Fig. 6. *Leiopteria*, sp.
Fig. 7. *Aviculopecten*, right valve.
Figs. 8, 9. *Streblopteria media*, sp. n., left and right valve.
Fig. 10. *Limatulina ohioensis*, n. sp., left valve.
Fig. 11. *Atrypa reticularis?*
Fig. 12. *Hemipronites crenistria?*, young.
Fig. 13. *Chonetes*, sp.
Fig. 14. *Chonetes pulchella*, Win.
Figs. 15, 16. *Nucula*, sp. ?
Fig. 18. *Productus arcuatus*, H.
Fig. 19. *Ostracode crustacean.*
Fig. 20. *Productus flemingi.*
Fig. 21. *Chonetes illinoisensis.*
Fig. 22. *Productus*, sp.
Fig. 23. *Spirifer striatiformis*, (cf. *tullia*, H.)
Fig. 24. *Productella ?*
Fig 25. *Productus nebrascensis.*
Fig. 26. *Spirifer striatiformis*, camera drawing of striae.
Fig. 27. *Productella* [illegible], right valve.
Fig. 28. *Productus* [illegible], var. [illegible], H.
Fig 29. *Hemipronites crenistria.*
Fig. 30. [illegible] *truncatus*, sp. n., dorsal view.
Fig 31. [illegible], Win. ?
Fig. 32. Hypostome of [illegible]

PLATE IV.

Fig. 1. See page [illegible]
Fig. 2. [illegible]
Fig. 3. [illegible]
Fig. 4. [illegible]
Fig. 5. [illegible]
Fig. 6. [illegible]
Fig. 7. [illegible]
Fig. 8. [illegible]
Fig. 9. [illegible]
Fig. 10. [illegible]

Fig. 12. *Palæoneilo elliptica*, upper figure, var. *plicatella* lower, var. *ailorismiformis.*
Fig. 13. *Grammysia hannibalensis.*
Fig. 14. *Microdon reservatus ?*
Fig. 15. *Nuculana simliis*, cast.
Figs. 16, 17. ?
Fig. 18. *Edmondia burlingtonensis*, ?
Fig. 19. Cf. Fig. 4, Plate IX.
Fig. 20. *Pteronites obliquus ?*

PLATE V.

Fig. 1. *Rhynchonella sappho* (Cf. *cooperi*), Congl. II.
Fig. 2. *Spirifer winchelli*,* dorsal valve. Congl. II.
Fig. 3. *Spirifer winchelli*, ventral valve.
Fig. 4. *Syringothyris cuspidatus*, front view.
Fig. 5. *Syringothyris cuspidatus*, ventral view of cast.
Fig. 6. *Syringothyris cuspidatus*, hinge view of cast.
Fig. 7. *Syringothyris cuspidatus*, diagramatic median section of ventral valve.
Fig. 8. *Platyceras hertzeri*, cast.
Fig. 9. *Orthis vanuxemi*, var. *pulchellus.*
Fig. 10. *Cryptonella eudora.*
Fig. 11. *Sanguinolites marshallensis.*
Fig. 12, (No. 1367.)
Fig. 13. *Spiriferina solidirostris.*
Fig. 14. *Hemipronites crenistria?.*
Fig. 15. *Schizodus cuneus.*
Fig. 16. Unidentified crinoid from congl. II.
Fig. 17. *Ctenodonta houghtoni ?*
Fig. 18. *Rhynchonella* sp.

PLATE VI.

Fig. 1, *Posidonomya (streblopteria) fragilis*, sp. n.
Fig. 1. *Spirifer marionensis*, ventral valve, Moots' Run, Licking Co.
Fig. 2a. do hinge view of same. Partial cast.
Fig. 2b. do hinge view of dorsal valve, cast.
Fig. 2c. do umbonal region of same.
Fig. 3. do dorsal valve. From concretions of lime 15 feet below horizon of No. 2.
Fig.. 3a. do hinge view of same.
Fig. 4. do ventral valve from same horizon.
Fig. 4a. do hinge view of same.

Fig. 5 and 5a. smaller valves of same species.
Fig 6. *Spirifer striatiformis*, dorsal valne. From exposure 1½ miles south-east of Granville.
Fig. 7. do. ventral valve, upper layers at Williams' quarry west of Granville.
Fig. 8. *Hemipronites crenistria*, dorsal valve, with Fig. 2, Moot's Run.
Fig. 9. do. From the freestone. ?
Fig. 10. *Allorisma cooperi.* Union Station freestone.
Fig. 11. *Productus semireticulatus*, dorsal valve.
Fig. 12. *Aviculopecten winchelli.* Freestone.
Fig 13. *Conularia newberryi ?* 13a. End view.
Fig. 14. *Nautilus ?* sp. Moots' run.
Fig. 15. ?
Fig. 16. *Productus concentricus.*
Fig. 17. Front view of Fig. 13.

PLATE VII.

Fig 1. *Leiopteria ortoni*, sp. n., 40 ft below congl. I.
Fig. 2. *Streblopteria media*, left valve. Large var. from about 75 ft. below congl. I.
Fig. 3. do.
Fig. 4. *Crenipecten subcardiformis*, 40 feet below congl. I.
Fig. 5. do.
Fig. 6. *Streblopteria media*, right valve.
Fig. 7 *Pteronites obliquus*.
Fig. 8 *Palæoneilo* sp.
Fig. 9. *Rhynchonella* sp.
Fig. 10.. *Sanguinolites marshallensis*, sp n. (1377.)
Fig. 11. *Spirifer marionensis*, (1361.)
Fig. 12. *Streblopteria gracilis*.
Fig 13. *Crenipecten* sp.
Fig. 14. *Streblopteria squama*.
Fig. 15. *Chonetes* sp.
Fig. 16. *Spiriferina octoplicata. ?*
Fig. 17. *Euomphalus* sp.
Fig. 18. *Productus shumardianus*, H.
Fig. 19. *Athyris*, sp.
Fig. 20. *Productus gracilis*.
Fig 21 ?
Fig. 22. *Chonetes logani*, ventral and dorsal valves.
Fig. 23. *Rhynchonella subcuneata ?*
Fig. 24. *Spirifer* sp. Freestone, Granville.
Fig. 25. *Rhynchonella sappho*.

Fig. 26. *Productus*, (cf. Plate III, Fig. 20.)
Fig. 27. *Goniatites* sp ?
Fig. 28. *Aviculopecten*, sp.
Fig. 29. *Modiola waverlyensis.*
Fig. 31. *Leiopteria halli.*
Fig. 32. *Leiopteria* sp. Moot's Run.
Fig. 33. *Allorisma* sp ? (No. 1378.)
Fig 34. *Athyris* sp.
Fig. 35. *Nuculana* sp. 30 feet below conel. I.
Fig. 36. ? do
Fig. 37. *Palæoneilo concentrica* var. do.
Fig. 38. *Platyceras* sp ?
Fig. 39. *Conocardium pulchellum.*
Fig. 40. *Conocardium pulchellum ?*
Figs. 41. *Conocardium* sp ?

PLATE VIII.

Fig. 1. *Sanguinolites aeolus.* Shale below congl. II, Newark.
Fig. 2. *Allorisma winchelli*, side view.
Fig 3. do hinge view.
Fig. 4. do front view.
Fig. 5. *Edmondia depressa*, side view.
Fig. 6· *Allorisma ventricosa*, M. do
Fig. 7 *Prothyris meeki.* do
Fig. 8. *Microdon ? triangularis* Freestone.
Fig. 9. *Conularia newberryi*, below congl. II.
Fig. 10. *Sanguinolites michiganensis.*
Fig. 11. *Sanguinolites aeolus*, small specimen.
Fig. 12. *Grammysia ventricosa*, Freestone.
Fig. 13. Shale below congl. II.
Fig. 14. *Orbiculoidea* sp. do
Fig. 15. *Pleurodictyum problematicum*, Goldf.
Fig. 16. *Ctenodonta* sp., nodules, Moot's run.
Fig 17. *Cyclonema ?* do
Fig. 18. *Spirifer ?* do
Fig. 19. *Chonetes.*
Fig. 20. *Bellerophon cyrtolites*, H., var. *cribristriatus*, var. n , above Freestone, Granville.
Fig. 21. *Bellerophon cyrtolites.* Shale below congl. II, Newark.
Fig. 22. *Bellerophon* sp ?
Fig. 23. *Loxonema Yandellana.*
Fig. 23. *Chonetes ?* nodules Moot's run.
Fig. 24. *Phillipsia ?* do

PLATE IX.

Fig. 1. *Sprifer marionensis.*
Fig. 2. Unidentified casts from "Dug-way."
Fig. 3. *Sanguinolites naiadiformis.*
Fig. 4. Unidentified.
Fig. 5. *Sanguinolites unioniformis.*
Fig. 6. *Oothonota rectidorsatus.*
Fig. 7. *Sanguinolites unioniformis.*
Fig. 8. do do
Fig. 9. do do
Fig. 10. do *flavius.*
Fig. 11. *Leda spatulata.*
Fig. 12. *Leda saccata.*
Fig. 13. *Palæoneilo elliptica.*
Fig. 14. *Nucula iowensis.*
Fig 15. *Palæoneilo elliptica.*
Fig. 16. *Nucula ?*
Fig. 17. *Edmondia burlingtonensis ?*
Fig. 18. *Arca ornata.*
Fig. 19. *Spirifer* sp.
Fig. 20. *Schizodus chemungensis.*
Fig. 21. *Hemipronites crenistria.*
Fig. 22. *Sanguinolites transversus.*
Fig. 23 *Palæoneilo attenuata.*
Fig 24. *Sanguinolites unioniformis ?*
Fig 25. ?
Fig. 26. ?
Fig. 27 *Edmondia burlingtonensis.*
Fig. 28. *Sanguinolites senilis.*
Fig. 29 *Bellerophon cyrtolites*, form with unusually irregular striae.
Fig. 30. *Bellerophon perelegans.*
Fig. 31. *Bellerophon cyrtolites*, cast.
Fig. 32. *Bellerophon galericulatus.*
Fig. 33 34. *Orthoceras indianense.*

PLATE X.

Fig. 1 *Schizodus newarkensis.*
Fig. 2. *Sanguinolites naiadiformis.*
Fig. 3. *Spiriferina depressa.*
Fig. 4. *Modiomorpha hyalea ?*
Fig. 5. *Allorisma nobilis.*
Fig 6. *Productus semireticulatus.*

Fig. 7. *Crenipecten winchelli.*
Fig. 8. *Aviculopecten granvillensis.*
Fig. 9. *Rhynchonella contracta.*

PLATE XII.

Fig. 1. *Phillipsia præcursor.* Head and pigidium.
Fig. 2. Unidentified. Moot's run.
Fig. 3. *Edmondia ?* Perhaps *Grammysia* sp.
Fig. 4. *Sphenotus contractus.*
Fig. 5. Unidentified Moot's run.
Fig. 6. *Productus shumardianus*, H.
Fig. 7. *Lyriopecten cancellatus.*
Figs. 8, 9, 4 *Pterinopecten cariniferus.*
Fig. 10.. *Crania hamiltonæ ?*
Fig. 12. *Rhynchonella* sp. Moot's run.
Fig. 13-15. *Entolium shumardianum.*
Fig. 16-17. *Aviculopecten cooperi.*
Fig. 18. Unidentified. Moot's run.
Fig. 19. *Crenipecten* (*færstii ?*) Cuahoga shales.
Fig. 20. *Spirifer striatiformis.* Dorsal valve.
Fig. 21. *Crenipecten.* Upper division of Waverly.
Fig. 22. *Crenipecten granvillensis.* Dorsal valve.
Fig. 23. *Goniodon ohioensis.* Exterior.
Fig. 24. *Goniodon ohioensis.* Cast of both valves.
Fig. 25. *Goniodon ohioensis.* Lateral view of same.
Fig. 26. *Euomphalis latus.*
Fig. 27. *Allorisma convexa.*
Fig. 28. *Athyris* sp ?
Fig. 29. Unidentified. Moot's run.
Fig. 30. *Orthoceras* sp ?
Figs. 31, 32. Fish scales. Moot's run.
Fig. 33. Unidentified. Moot's run.
Fig. 34. Unidentified. Moot's run.
Fig. 35. *Sanguinolites*, resembling *marshallensis.* Moot's run.
Fig. 36. *Bellerophon* sp. Moot's run.
Fig. 37. *Naticopsis* sp. Moot's run.
Fig. 38. *Platyceras* sp. Moot's run.
Fig. 39. *Cyclonema strigillata.*
Fig. 40. *Stictopora striata.*
Fig. 41. Unidentified.
Fig. 42. (See Fig. 8.)
Fig. 43. *Productus shumardianus.*

ERRATA.

Page 12. Title. Instead of PART IV, read PARTS III and IV.

Page 24. 17 lines from bottom. Instead of C. TUMIDUS, read C. SUBCARDIFORMIS.

Page 27. 2 lines from bottom. Instead of RESPONSILITY, read RESPONSIBILITY.

Page 31. Under Prod. semireticulatus. Instead of VII, Fig. 11, read VI, Fig. 11.

Page 42. 15th line. Instead of SITUATION, read SINUATION.

Page 42, et seq. Instead of S. CENTRONATA, read S. CENTRONOTA.

Page 65. Instead of SCHIZODUS MEDINENSIS, read SCH. MEDINAENSIS.

Page 72. Instead of ALLORISMA COOPERII, read A. COOPERI.

Page 80. Instead of PALÆONEILO ELLIPTICUS, read P. ELLIPTICA.

Page 80. Instead of CARDINIA, read CARDINIA.

Page 84. Instead of GONOIDON read GONIODON.

Page 87. Instead of ENOMPHALUS, read EUOMPHALUS.

III.

CROSS-FERTILIZATION OF LOBELIA SYPHILITICA.

BY C. L. PAYNE.

The methods of bringing about cross-fertilization are very numerous. But it has been observed that the methods of fertilization conform to a few leading principles and types. And according to these principles the methods of cross fertilization may be divided into classes. The various modifications in the orders, genera, and species under these leading classes are only different applications of these principles and different methods of conforming to them. Thus we have the principle, that open flowers can be fertilized by the wind, and according to this principle we have a large number of plants, whose flowers are completely exposed to the wind. But in other respects the flowers may vary to suit the habits and circumstances of the several plants. Again, there is a principle, that melliferous plants attract insects and can make them the agents of cross-fertilization by adapting their contrivances for fertilization to them. These two principles are sometimes combined, and such plants have two chances for bringing about cross-fertilization. Here, also, there are many modifications. There are many other principles with contrivances adapted to them. A classification based upon these principles, it seems, would be as convenient as the general classification of plants. But of couise it is hard to find a suitable principle of division. Hildebrand has made a very excellent classification for phanerogamic flowers, according to the completeness with which they exclude self-fertilization. According to his classification the plant we have under consideration would come under class B. Male and female organs in one and the same flower (monoclinism), division 1. The organs of the two sexes not developed simultaneously (dichogamy), and subdivision (a.) The male before the female. And the division might have been carried farther, as there are several minor principles applied in different ways to the plants under the last division.

One of the most wonderful of the many contrivances for cross-fertilization is found in the lobelia family. The calyx is adherent to the two-celled ovary. The corolla is two-lipped; the lower lip is three-lobed; the upper lip is split and the division continued to the base of the corolla. Through this slit the united filaments and anthers bend out then in again over the lower lip. The anthers unite and form a conical-shaped figure. The upper portion projects beyond the lower (as in the case of a bird's beak) and forms the apex of the cone. A spur extends downward from this upper portion, forming a hollowed space. A clump of stiff hairs extends from the lower lip, and presses closely up to the tip of the apex, closing the hollowed space, except a small opening between the hairs and the spur in the back end. Now the pistil is sheathed by the stamens. It has a broad two-lobed stigma. Each lobe is protected by a sheath thickly covered with a ring of stiff hairs. At first the pistil is considerably below the lower extremity of the anthers. The pistil keeps growing up through the tube of the filaments, until it enters the chamber of the anthers at the proper time for fertilization. The inner walls of the pollen cells have by this time been absorbed, and the pollen has been let loose in the chamber. The pistil steadily presses the pollen toward the vertex. Escape backward is prevented by the broad stigma-lobes with their ring of hairs, thus some of the pollen is pressed into the little space at the vertex. When a bee alights on the lower lip and crawls down the tube, the slit in the back of which allows it to be expanded, the back of the bee bends down the stiff hairs. The pollen is hurled out upon it because of the tension. The pollen is carried to another flow- and deposited on the stigma in the manner immediately to be ex- ed. The pistil pushes on, driving out the pollen, and grows h the aperture in the vertex, protruding over the lower lip. ore fertilization has been prevented by the sheaths. These are now opened, and the stigma laid bare to catch the pollen from the bee's back, where it has been deposited by another flower, as previously described.

The general arrangement for cross-fertilization in the florets of the Compositæ is the same as that just described for the Lobeliaceæ. But the vast number, the wide distribution, and the varied habits of the genera and species under the Compositæ cause many special variations. These variations are shown especially by the arrangements of the hairs and the stigmatic papillæ. In some genera, just as in the Lobelia, these hairs sweep the pollen before them, forming a simple ring around the style at the base of the stigmas or aggregated in a tuft at the extremity of the stigmas. In other genera they spread over more or less of the surface of the style and the pollen is entangled among them. The mechanism for pushing out the pollen is farther perfected in some Compositæ by the contraction of the filaments of the stamens on being touched by the proboscis of the insect.

IV.

LIST OF DIATOMS FROM GRANVILLE, OHIO.

BY J. L. DEMING.

Diatoms are microscopic unicellular algæ. Though they were formerly regarded as belonging to the lower orders of the animal kingdom, microscopists are now agreed in placing them among the Plantæ. They are generally of a brown color, though frequently becoming greenish when dry. The endochrome, as the colored contents of the valves are called, is always symmetrically arranged. Each cell is composed of two similar and apparently parallel portions, the valves. These valves, although nearly equal in length, are not of the same width; in fact they differ greatly. In consequence of the fine striations and other markings of the silicious valves, they constitute valuable tests of the value of microscopic objectives.

Diatoms may be often seen to move a little in the water or slime in which they exist. This is especially so in the case of the more elongated forms and for this reason they were regarded as having an animal nature; but it is now no longer believed to be so any more than in the case of the moving vegetable zoospores. There are many theories concerning the movements of Diatoms, but the most plausible one to me is, that heir motion is due to the process of imbibing and emitting fluids in process of their vegetable life.

Diatoms may exist as individuals, singly or in loose families; they are free or attached to other objects by little stipes, and are frequently imbedded in a mucous secretion. The free forms are locomotive and may be seen in constant motion under the microscope.

In the process of reproduction they bear a close resemblance to to the Desmids. They increase by division (whence the name from

Diatomos, a through-cutting), which takes place, not transversely, but longitudinally; and the lines which mark its progress are almost always visible in them. In this process of division new valves are formed along the line of division, the old ones remaining on the outer sides, and each new diatom cell having an old valve and a new one. But sexual reproduction takes place by conjugation and by the formation of auxospores, which restores periodically the normal size of the species.

Diatoms are quite abundant in the vicinity of Granville, Ohio, some of them being rare specimens. The following list I have identified for the most part, by recourse to the photographic plates from Aldolf Schmidt's "Atlas der Diatomaecen-Kunde."

Cymbellæ gastroides, K.
Navicula polystricta, Gru.
Navicula polystricta, (var.) *circumstricta*, Grunow.
Navicula sentelloides, Sm. Domb.
Navicula Cynthia, A. S. Java.
Navicula cuspidata.†
Navicula borealis.‡
Navicula cryptocephala.‡
Navicula entomon.‡ E.
Navicula biceps. E.
Navicula latissima, Greg.‡
Navicula consimilis, A. S.
Navicula lanceolata, K.
Navicula brevis, Greg.
Navicula latissima, (type), A. S.
Navicula longa, Greg.
Nitzschia coaretala.‡
Pleurosigma Spenceri, ‡.
Gomphonema acuminatum, E.
Fragilaria lanceolata. ‡.
Diatoma meridian-circulare.‡
Friceratium solenoceros, E.
Friceratium Jensenianum, Grunow.
Friceratium venosum, Brighton.

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†. Not typical, but probably a variety.

‡. Identified by plates in Indiana Geol. Rep. Vol. II

Note.—Circumstances making it convenient to issue both parts at once, what follows may be regarded as Part II of Vol. III.

V.

NOTES ON PALEOZOIC FOSSILS.

BY AUG. F. FOERSTE.

CAMBRIAN.

MICRODISCUS PUNCTATUS, *Salter.*

(*Plate* XIII, *Fig.* 5.)

This species was described by Salter, (Quart. Journ. Geol. Soc., 1864,) from the Lingula-flags of Wales, at Porth-y-Rhaw. The head is semi-circular and the margins at the postero-lateral angles are slightly bent out again, forming almost a right angle with the posterior margin. The margin around the lateral and anterior portion of the head has an elevated border at the edge, which is cut transversely by numerous short grooves, giving it the appearance of a row of minute, closely set tubercles. The lateral lobes do not approach very closely to one another in front of the glabella, leaving quite a distinct vacant space. The glabella terminates posteriorly in a long spine. One of the accompanying figures, enlarged, represents the spines as equalling the length of the head; another, drawn natural size, could under no circumstances be considered longer than two-thirds of the head, and in fact is drawn only half as long. This would suggest that the spine of the enlarged figure is overdrawn, or that it was of an exceptional length. The middle lobe of the pygidium is said in the description to have seven segments. But the drawing of an enlarged specimen represents seven segments very plainly, and suggests an eighth, and even a terminal indistinct tenth one by means of the shading.

In North America, in the St. John's Group at Ratcliff's Millstream, New Brunswick, is found a very similar form. There seems to be more variation in the form of the glabella, this often becoming more or less distinctly lobate on either side. The lateral lobes always approach to within a short distance of each other anteriorly, being separated by a deep groove rather than by a vacant space. The terminal spines of the glabella is also extremely variable, being quite short and rather blunt, or equalling two-thirds the length of the glabella, when it is very slender posteriorly. The edge of the margin often presents the milled appearance noted in the European form, this varying to a series of closely set tubercules. The middle lobe of the pygidium usually presents nine well marked segments and under favorable circumstances some of the finest specimens will show a tenth quite distinctly, and even faint indications of two more. Both head and pygidium are covered with minute granules.

Mr. Walcott, in his excellent monographs of our Cambrian fauna, referred the American specimens to the Welsh species, with a certain reservation on account of variations observed, and suggested the application of the name proposed by Mr. Hartt, *M. pulchellus*, in case they were found to be distinct. Our own investigations lessen, rather than increase the differences then observed..

CINCINNATI GROUP.

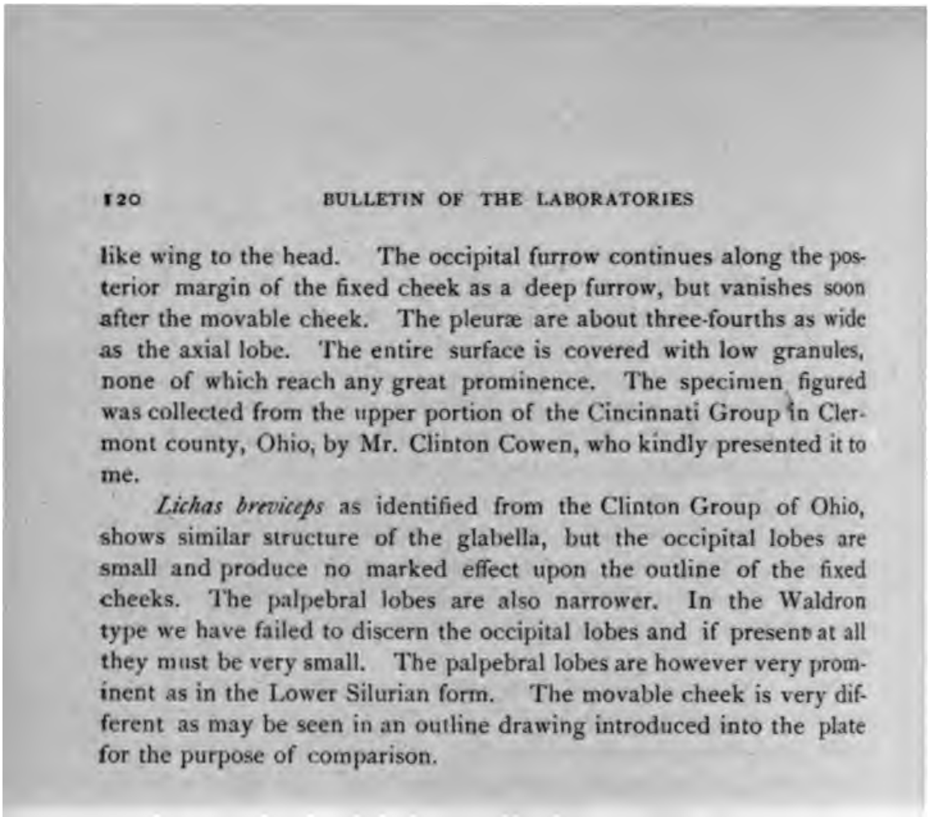
LICHAS HALLI, *sp. n.*

(*Plate* XIII, *Fig.* 4)

In 1842. Conrad described *Lichas Trentonensis* from the Lower Silurian rocks of New York. In the first volume of the palentological reports of that state, Hall re-described it and at the same time illustrated it in the accompanying plates. Among the illustrations on plate 64, figure 1e, is a specimen from the vicinity of Cincinnati, and manifestly distinct from the typical forms of *L. Trentonensis.*

For the sake of comparison we have outlined (Plate XIII, fig. 8,) the glabella and accompanying parts of *Lichas Trentonensis* as it occurs at Trenton Falls, New York. The sides of the middle lobe of the glabella are but very slightly divergent posteriorly, reaching the occipital ring without any change of direction, therefore not forming a pestle shaped widening at the posterior end of this lobe. The lateral lobes also reach the occipital furrow, their sides preserving the same degree of curvature behind the palpebral lobes until they reach the occipital furrow. The facial sutures extend from the palpebral lobe with a short curve laterally and posteriorly to the posterior margin of the head. The fixed cheeks occupy *all* of that portion of the head which lies between the facial sutures, the palpebral lobes, and the lateral lobes of the glabella. Beginning near the posterior termination of the facial suture, a furrow, narrow but distinct, runs with a moderate curvature along the movable cheek forwards, within a moderate distance from the eye.

The Ohio specimens we propose to name *Lichas Halli* after the illustrious state geologist of New York. The sides of the middle lobe of the glabella at a short distance from the occipital furrow make a rapid double curve laterally, then incurve slightly until they reach the occipital furrow, giving by this means to the posterior end of the middle lobe of the glabella a shape somewhat like that of an apothecary's pestle, and which is characteristic of quite a distinct section of the genus *Lichas*. The sides of the lateral lobes of the glabella converge posteriorly and meet near the lateral edges of the pestle-like formation just described, but do not extend to the occipital furrow. Between the postero-lateral terminations of the lateral lobes, the lateral portions of the pestle-like termination of the middle lobes, the occipital furrow, and the fixed cheeks lie very marked lobes, which from their proximity to the occipital furrow may be called occipital lobes. In consequence of these lobes the inner posterior edge of the fixed cheeks is considerably incurved. The glabella as a whole is rather flattened above but anteriorly it curves rather rapidly down to the anterior margin of the head. The palpebral lobes are rather large. There seems to be no distinct furrow on the movable cheeks running from the anterior to the posterior sides of the same. The interpretation of the structure of the cheeks is not so clear from the specimens at hand but seem to follow some of the more familiar types. The posterior margin of the fixed cheeks namely curve forward, joins the posterior margin of the movable cheeks, the latter curving backward and forming with the anterior edge of the movable cheeks a broad, pleura-



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like wing to the head. The occipital furrow continues along the posterior margin of the fixed cheek as a deep furrow, but vanishes soon after the movable cheek. The pleuræ are about three-fourths as wide as the axial lobe. The entire surface is covered with low granules, none of which reach any great prominence. The specimen figured was collected from the upper portion of the Cincinnati Group in Clermont county, Ohio, by Mr. Clinton Cowen, who kindly presented it to me.

Lichas breviceps as identified from the Clinton Group of Ohio, shows similar structure of the glabella, but the occipital lobes are small and produce no marked effect upon the outline of the fixed cheeks. The palpebral lobes are also narrower. In the Waldron type we have failed to discern the occipital lobes and if present at all they must be very small. The palpebral lobes are however very prominent as in the Lower Silurian form. The movable cheek is very different as may be seen in an outline drawing introduced into the plate for the purpose of comparison.

UPPER SILURIAN—AMERICA.

STROMBODES PYGMÆUS, *Rominger*.

(*Plate* XIII, *Fig.* 18.)

In the Dayton limestone of Ohio, Mr. Van Cleve found a fossil which he labeled as *Sarcinula organum, Lamarck*. This is a form resembling Rominger's species above cited in apparently every particular except in the character of the elevations into which the pits of the calyces are sunk. These are somewhat more prominent than the figure accompanying the original description would lead one to suspect; but the difference is not so great that our specimens might not readily be a slight variation from the type. The interior of the pits is 2 mm. in diameter. The elevations are referred to series in one direction more readily than in any other, but still there is considerable variation in the distance between any two elevations. Six millimeters is the average distance, but this varies rapidly in different parts of the same specimen from 4 to 10 mm. The elevation of even the most prominent malliform cones does not exceed 2 mm. It is noticed that the rugæ which striate the surface are more or less radial at the mouth of the pits but as they descend the elevation they rapidly take a common direction and become quite parallel and more or less wavy between the elevations. The direction of the striæ then is transverse to the direction in which the elevations are said to be more readily referable to series. This arrangement is very common in the genus *Smithia* of Edwards and Haine, a subgenus of *Phillipsastræa*, D'Orbigny.

The specimen referred to this species by Mr. William J. Davis, (Kentucky Fossil Corals, Pl. 123, Fig. 1,) has not the slightest resemblance either to the type or to the Ohio specimen here under consideration; it belongs rather to that smaller variety of *S. pentagonus* which is usually regarded as typical of the species. *S. incertus*, *Davis* of the same plate is a good medium sized specimen of the same species. *S. pentagonus*, Fig. 3, of Pl. 121, is a similar form with a slightly less distinct margin around the pits in the centre of the calyces. *S. striatus*, Fig. 1, of Pl. 122, represents one of the larger varieties. A form slightly less in size, with more defined margins about the pits, is figured by Rominger, Fossil Corals, Pl. 48, Fig. 1. His figure 2 of the same plate represents one of the smaller forms. The species is extremely variable both in the size of the calyces, and in the fineness of their radial striations. Variation is however the normal condition of species of wide geographical distribution.

SPHÆREXOCHUS MIRUS, *Beyrich*.

(*Plate* XIII, *Fig.* 6.)

Since Hall, in the Geol. Rep. of Wisconsin, 1862, separated *Sph. Romingeri* from *Sph. mirus*, on account of distinctions presented by the pygidia at that time associated with undoubted glabellæ of a species of *Sphærexochus*, it has been the fashion of American paleontologists to refer all American specimens to Hall's species. To show that this is probably incorrect, a description of the glabella of a specimen obtained in the Guelph at Cedarville, Ohio, is appended, which will be seen to agree even in the minutest details with the European forms referred to Beyrich's species.

Glabella almost hemispherical, slightly broader than long; two small lobes cut off a part of each side of the glabella at the occipital furrow, their diameter is about two-thirds of the distance which separates them, or but slightly less. The groove defining these lobes, the occipital furrow, the groove separating the fixed cheeks and then defining the anterior margin of the glabella are all very distinct. The facial sutures begin to define the fixed cheeks at a point near the upper margin of the lateral lobes of the glabella, then they pass within a moderate distance of the lateral lobes to a place slightly behind the middle of these lobes, after which they turn quite abruptly outward and then curve backward to the posterior margin of the head. At a point rather beyond the middle of the occipital border of the fixed cheeks, near the edge, there is a low tubercle. On each side of the glabella are two faint grooves which are readily overlooked, especially in casts. When examined however with a magnifier, and with the light thrown in the proper direction, they are really quite distinct. The first pair lie about two-thirds the diameter of the lateral lobes above their anterior margin; the second pair lie about the same distance beyond the second. Being short they are not readily seen in a view from above. The head parts of the Ohio specimens are therefore seen to agree perfectly with those of the European *Sph. mirus*. The pygidium associated with the Wisconsin species belongs to *Ceraurus Niagarensis*, as Hall himself afterwards noted. We fail therefore to discover what the distinguishing features of *Sph. Romingeri* are, but Ohio specimens at least belong to *Sph. mirus*.

UPPER SILURIAN.—AUSTRALIA.

ENCRINURUS BROWNINGI, *sp. n.*

(*Plate* XIII. *Fig.* 7.)

The glabella is very much rounded and inflated for about two-thirds its length anteriorly, the posterior third is much narrower, about half the greatest width of the anterior parts, slightly widening behind, thus giving a marked concave outline to the sides of the glabella. The occipital furrow is itself not very deep, but the border behind it is elevated to such a degree as to give it some importance. Along the posterior half of the glabella the tubercles are arranged in quite distinct transverse rows. In the specimen figured, the first three rows have four tubercles in each, the first from the occipital groove being quite small, increasing in size rapidly in the other two. The fourth row contains six tubercles of large size. After this the tubercles remain large but have no longer a regular arrangement transversely. The large size of the tubercles is very marked and characteristic. The eyes are about in line with the space between the second and third row tubercles. The groove separating the fixed cheeks is very deep. The fixed cheeks begin a slight distance behind the widest part of the glabella. The distance between the eyes is equal to the length of the glabella and occipital ring. Posterior to the eyes, the facial sutures make a sharp angle with the continuation of the occipital furrow. Immediately behind the eyes there are two rows of small tubercles which soon merge into one. Between the eyes and the glabella are the largest tubercles on the fixed cheeks, but even there are much smaller than those of the glabella. The continuation of the occipital furrow over the fixed cheeks is deep and narrow at first, rapidly widening and becoming shallower towards the postero-lateral margins of the head. The posterior border of the head is distinctly raised, defining the occipital furrow very well. If very carefully examined it shows low tubercles along its summit, but these might be readily overlooked.

Mr. S. G. DeKoninck, in Foss. Pal. Nouv. Salles du Sud., cites the occurrence of *E. punctatus*, *Brunnich* at Yass, 8 mi. southeast of Bowning, and also at Duntroon. But our specimen is evidently not of that species. The fact that the postero-lateral ends of the head in that species are sharp, acutely pointed would be sufficient to distinguish that species from ours. The shape of the glabella is also very different, as is well shown by a typical European specimen which has been introduced into our plate for the sake of comparison. Since the specimen from Duntroon however is said to be quite perfect we may also safely add that our specimen belongs to a different species from that of Duntroon as identified by DeKonnick.

Mr. R. Etheridge, Jr., has cited the same species, *E. punctatus*, from Bombala, but the material was not entirely satisfactory.

Mr. S. G. DeKoninck described *loc. cit.*, a new species *E. Barrandei* from Yarralumla. He says however that the furrow separating the fixed cheeks from the glabella is feebly indicated, whereas in our specimens it is very marked. It resembles our specimen in the entire loss of the pointed ends of the movable cheeks which are so prominent in *E. punctatus*. Judging by the figure the tubercles are considerably smaller on the glabella, and far more numerous; there is a greater distance between the eyes and the continuation of the occipital furrow, and this is occupied by a greater number of rows of tubercles; three. This is evidently the most closely related species, but if his drawing is at all correct then our species is quite distinct.

ENCRINURUS MITCHELLI, *sp. n.*

(*Plate* XIII, *Figs.* 2, 3, 20.)

Glabella anterior to the facial suture not known in the larger specimen; the facial suture gives the anterior outline of the remainder of the glabella an evenly rounded appearance. The sides of the glabella are moderately concave, widening anteriorly, having the greatest breadth at two-sevenths its length from the occipital furrow. On either side along the dorsal furrow are a row of large and very conspicuous tubercles or lobes which form a marked contrast with the rather small tubercles on the remainder of its surface. In the specimens before us there are five of these; the fiıst is ccmpressed antero-posteriorly, the next three are well develeped, and the fifth is considerably smaller than these. The remainder of the glabella is rather thickly set with small tubercles. The fixed cheeks also have more conspicuous tubercles along the dorsal furrow, of about half the size of the corresponding tubercles on the glabella, and alternating with them, the eyes are about equally distant from the dorsal furrow and the continuation of the occipital furrow. Posterior to the eyes the facial sutures form a very sharp angle with the occipital furrow cutting the lateral margins of the head just at furrow; at first two rows of small tubercles separate them, quickly merging into one. The tubercles increase in size toward the dorsal furrow. A moveable cheek belonging to the more broken specimen shows that the deep dorsal furrow after sharply defining the anterior part of the fixed cheeks, makes an equally prominent depression as it enters the moveable cheek, quickly decreasing in depth and broadening as it turns backward along the margin of the head. The part anterior to this groove according to the general morphology of the genus *Encrinurus* once must have formed the anterior part of the glabella. Like the adjacent parts of the glabella, it is covered with small tubercles. The cheeks posterior to the grooves have but few tubercles and these are also small. The occipital furrow is well marked, and the occipital occipital margin is raised and distinct. The thorax is composed of twelve segments. The middle lobe is about three-fifths as wide as the lateral lobes. If characterized by well marked tubercles the specimens before us do not show them. The pygidium is triangular, broader than long, in the ratio of seven to five. The central lobe anteriorly is equal to about half the breadth of the lateral lobes. The lateral lobes with nine distinct anchylosed segments, with a possible tenth. These apparently without tubercles. The middle lobes with about twenty-eight transverse ridges. In casts these are broken or even indistinct along the middle of the lobes. Beginning with the fourth ridge every fourth succeeding ridge bears a tubercle at the middle. While studying the *Encrinuridæ* the question has often raised itself whether tubercles prominent in the cast might not be entirely absent on the surface of the pygidium itself but unfortunately we have never had the proper material to determine this question.

Two species closely related to *E. Mitchelli* have already been described from Australia by Mr. L. G. DeKoninck. The first is *Cromus Bohemicus, Barrande.* A comparison with the Bohemian species however shows marked differences. The large tubercles at the dorsal suture are in the Bohemian species represented as lobes with the smaller tubercles of the remainder of the glabella also present on them. The eyes are farther removed from the occipital furrow. There are twelve well marked ridges on the lateral lobes of the pygidium, the summit of which is represented as being flat while in ours they are distinctly rounded. The sides of the pygidium are also represented as being denticulated; in our specimens traces of a similar structure are visible but they are not sufficiently distinct for delineation. The description of the specimens from Yarralumla makes it probable that these are also distinct although closely related.

The pygidium of the second species described, *Cromus Murchisoni, L. G. De Koninck* is said in the text not to have been found. The pygidium figured in the plate and mentioned in the explanation of the same, undoubtedly was associated by him with his *Encrinurus Barrandei* of the same plate, and agrees well with his description of that species. *Cromus Murchisoni* is readily distinguished from our species by the absence of the large tubercles along the dorsal furrow, the arrangement of the posterior tubercles in transverse rows (a fact not observed in ours; indeed it suggests in this our first species, but the anterior of the glabella is not round; the drawing evidently leaves much to be desired), and the greater distance of the eye from both dorsal and occipital furrows.

PHACOPS SERRATUS, *sp. n.*

(*Plate* XIII, *Fig.* 1.)

Head with semi-circular outline, almost twice as broad as long. Anterior lobes of the glabella equalling eight-elevenths of the length of the head; its anterior margin, instead of being regularly rounded as is usual in most species of *Phacops*, is rounded most at the middle of its outline and at its junction with the dorsal furrow, giving the intermediate outline on each side a somewhat compressed appearance. The curvature of the sides of the glabella is small, they converge posteriorly and form an angle of about seventy-five degrees with each other. With the exception of a faint median elevation the surface is quite flat, above bending rather abruptly into the dorsal furrows and at the anterfor margin even becoming incurved. The specimen is slightly exfoliated so that it is impossible to say if there were any grooves on its surface, but if so they must have been rather inconspicuous. It is covered however with low small tubercles. This lobe of the glabella is defined posteriorly by a furrow which is quite marked at the sides, but toward the middle it becomes very shallow forming a sort of axis, and curving more or less forwards. This furrow cuts off from the remainder of the glabella two small posterior lobes, at either side considerably depressed below the general level of the glabella and terminated with a small knob. posteriorly it is defined by the well marked occipital furrow The occipital ring is very broadly subtriangular and is terminated with a distinct, short, pointed projection, which repeats itself on all the segments of the axial lobes of the thorax, gradually becoming indistinct, and vanishing soon after reaching the first ring of the axial lobe ot the pygidium. The eye has a reniform outline and extends from a short distance behind the point of greatest width of the glabella to within a short distance of the continuation of the occipital furrow. The palpebral lobe is strongly defined by a very distinct furrow which also outlines the posterior parts of the eye.

There are sixteen vertical rows of lenses in the eyes and the largest row seems to have contained nine lenses, but this can not be determined since the eye seems to be a little injured below. That part of the fixed cheek which lies between the eyes and the dorsal furrow seems strongly arched, behind the eye this cheek is very narrow and then it widens but moderately before meeting the occipital furrow, which curves forward along the side of the head and here, meeting the furrow defining the posterior part of the eye, bends forward giving great relief to the eye, and running in a much less distinct form along the base of the incurved front of the glabella. The occipital furrow is everywhere very distinct. The postero-lateral outlines of the head are rounded. The thorax consists of eleven segments, The middle lobe is almost as broad as the lateral lobes, on account of the quite sudden lateral deflection of the pleuræ at about half their length. The sides of the segments of the middle lobe are more or luss curved forward, and are slightly thickened. The length of the pygidium is equal to about two-thirds its width. The middle lobe of the pygidium at its anterior portion is about two-sevenths as broad as the pygidium; it tapers quite rapidly posteriorly. It is marked by seven transverse rings of which the sixth is very low and the seventh is very indistinct. The pointed tips already mentioned are readily noticeable only on the first ring, on the second they are represented by a low granule, on the third this becomes indistinct, on the fourth they disappear. The lateral lobes are marked by six ridges of which the sixth is indistinct. The first ridge is quite broad and is marked by a well defined although shallow furrow. On the second ridge this furrow becomes narrower, on the third it is no longer noticed. The furrows defining the middle lobe are distinct and give it a high relief.

In Prodr. Pal. Victoria, Dec. III. 1876, Prof. McCoy described from the Upper Silurian beds at Yering *Ph. fecundus*, *Barrande*. Since this is the species most closely related to ours we compared our specimens with the Bohemian species with the following results. In the Bohemian species the compression on each side along the anterior of the glabella is not noticed, this part of the glabella being evenly rounded. The anterior lobe of the glabella is characterized by distinct narrow lunate furrows, of the arrangement typical with this genus. The middle lobe of the pygidium is less tapering posteriorly, and contains eight well characterized transverse rings in addition to a small terminal piece. The ridges or anchylosed segments of the lateral lobes are all distinctly grooved along their summit. The feature upon which we place the most stress however is the line of pointed elevations along the median line of the animal, beginning with a very conspicuous termination of the occipital ring and ending with a few low granules on the pygidium. These give the axial lobe when viewed from the side quite a serrated appearance. If these be not of specific value, the species fails and becomes mere variety.

CYATHOPHYLLUM AUSTRALE, *sp. n.*

(*Plate* XIII, *Figs.* 12, 13, 14.)

Externally the polyp is marked by quite distinct costæ. The polyp is conical, slightly curved, the side towards the apertural gap being the more convex one. Fine striæ or lines of growth, with wrinkles of no prominence, pass around the polyp. Lamellæ in the calyx, 40, low and rounded, nearly rounded above, half of them disappearing soon after reaching the bottom of the calyx. Between the lammellæ in the groove is a series of minute points, about 11 of which occurs in a length of two mm. Length of polyp, 16 mm; breadth, 10 mm, depth of calyx at least 5 mm, it may have been a little greater. Found in the hardened grey-brown shales east of Bowning Hill, Bowning Parish, New South Wales, Australia. Presented by Mr John Mitchell.

In Pal. Foss. of Cornw. Dev. and W. Som. Mr. John Philips figures under the name of *Turbinolopsis bina, Lonsdale* a species presenting many of the characteristics of the Australian species. A row of small pits is found in the bottom of the grooves, but they are less numerous. The line of elevation between the pits is also noted in the Australian form, but the denticulations of the lammellæ noted in the English species are absent or at least not noticeable in our specimens. A form similar to the last is described by Mr. Rudolph Ludwig in Coroll. aus Pal. Form. under the name *Zaphrentis caudata.* The number of pits in the groove between the lamellæ is larger than in the English species; the denticulations of the lamellæ are smaller in number than the pits between them agreeing in this with the English species. The calyx is deep, at the centre it seems from the casts to be still further depressed, and on the side there seems to have been a distinct septal fovea. These species all agree in having a deep calyx, the lamellæ along the calyx are low, not reaching into the calyx, and instead of small transverse leaflets between the disseppiments as in *Cyathophyllum*, there are only minute pits. They however belong to that class of fossils typified by *Cyathophyllum* and form a connecting link with *Zaphrentis*. The pits may be said to represent the spaces between the disseppiments in *Cyathophyllum*, and the denticulations in the last two species, the coarser denticulations of the sub-genus *Heliophyllum*. We think it convenient to establish another subgenus for these aberrant forms and as such suggest *Palæocyathus*.

CYATHOPHYLLUM PATULA, *sp. n.*

(*Plate* XIII, *Figs.* 9, 10, 11.)

Polyp very much much broader than long. One at hand is 10 mm. high, 35 mm. broad in one direction, and 29 mm. broad in a direction at right angles with the last. Another specimen was 8 mm. high, 42 mm. broad in one direction, and about 34 mm. at right angles with this. A third specimen was about 9 mm. high and 22 mm. broad. So that the variation is evidently a matter of breadth more than that of length. The shape of the polyps would indicate as much. For a distance of about 8 mm. from the centre the base of the polyp shows its greater convexity, or rather, increase in hight, and this is also the thickest part of the polyp itself. Beyond this radius it rapidly grows thinner, its thickness usually being 2 mm. or less, so that in a large sized polyp there may be a thickened centre of about 16 mm. diameter and a very fragile border of 12 mm. or more entirely around the margin. This *border* is always flattened on the side of the central gap. The entire coral is always curved very decidedly upwards on the side of the apertural gap. Sometimes this curvature is even and rounded, often it is more or less irregular and broken by striæ of growth. This difference in growth between the side at the central gap and that at the apertural gap places the centre of the coral always considerably closer to the apertural gap. In the first specimen above noted the centre of the coral is 11 mm. from the apertural gap and 16 mm. from the central gap. It may be noted that in all corals of this group I have examined the side of greatest curvature was always on that of the apertural gap, and that if anywhere a concave curvature took place it appeared strongest nearest the base of the coral on the side of the central gap. Exteriorly the coral is marked by the radiating costæ, by lines of growth, which usually are not very prominent nor closely set, and by much finer concentric striæ, best seen by aid of the magnifier. Interiorly the polyp is seen to be composed of a large number of lamellæ, among which there is very little increase by intercalation, this usually taking place through successive implantations at the various gaps. As might be judged from the thinness of the coral, the lamellæ are not very much raised above the epithecal covering. Excepting near the center they are little more than low ridges. At the center they seem to be slighlly twisted together and to be slightly depressed, forming a narrow shallow cup; our specimens do not show this part well. The number of the lamellæ of course varies with the breadth of the specimen. In the first specimen mentioned there were about 130; the average is 12 or 13 along the margin in a distance of 10 mm. A cross section near the center of the coral shows that at this point the lamellæ are thin and are crossed by vesicular tissue. The lamellæ along the sides are much indented in a manner similar to that characteristic of the subdivision of this genus known as *Heliophyllum*. I however know of no form of this genus which has any resemblance to this species. Like the species last described it forms an interesting aberrant varation of the genus.

It will be noticed that *S. G. De Koninck* quoted *Ptycophyllum patellatum*, *Schlosheim* from Dangelong. This is a species very similar in form, may however be ever be superficially distinguished by the fact that it has conspicuous elevations of long and short lamellæ, and that these begin to be twisted already at a short distance from the centre.

CYATHOPHYLLUM BOLONIENSE, *Blainville*?

(*Plate* XIII, *Fig.* 15.)

Corallum composed of numerous polygonal polyps. Polyps typically five or six sided, but often with four, seven, or eight sides on account of the unequal compression of the polyps. Their walls are not perforated, those of adjacent polyps are not intimately connected so that in case of fracture, the coral often splits along the middle of these walls Weathering will often loosen the polyps in a similar way. The broken coral then assumes a columnar appearance. The columns are longitudinally corrugated at regular intervals by continuous ridges, five or six on each side of its polygonal outline; and also transversely corrugated. but at very irregular intervals. There are also numerous transverse striæ, which appear under a lens. Interiorly it consists of about thirty-five lamellæ which extend from the walls towards the centre. The greater part disappear before reaching a distance within one milllimetre of the centre, and of the rest occasionally one or two reach the very centre; in that case some-of them sometimes seems to pass on for a slight distance beyond the center. The spaces between these lamellæ are occupied by vesiculose leaflets or dissepiments.

We do not believe that this species is really identical with the French species, but the structural similarity is greater with this species than with any other known to us. The Australian form however has a smaller number of lamellæ, in a cross section they are seen to be often more or less wavy, and not uniformly straight as our figure would indicate, the number of disseppiments is also slightly less numerous than there represented. The general effect is however well given. These minute differences were noticed after the drawings were made. It differs from *C. hexagonum, Goldfuss* in the absence of a zone of thickening in the lamellæ about the centre of the polyp. From *C. rugosum, Edw. and Haine* it differs according to Rominger's identifications, in the much smaller number of dissepiments, and in the fact that the lamellæ do not lose their character at a certain distance from the centre and then continue are mere ridges over the tabulæ. The interior termination of the lamellæ is far more regular.

While our specimens show a close structural affinity with *C. Boloniense*, the fact that we have not well preserved views of the calyces prevents our determining whether the slight variations observed are specific or varietal in nature.

ENDOPHYLLUM ———.

(*Plate* XIII, *Figs.* 16, 17.)

Corallum composed of numerous polyps, polygonal or hexagonal in outline and separated by thin walls. These walls are most readily detected in weathered specimens, on account of yielding most readily to the dissolving action of the atmosphere. In cross sections they are seen as thin wavy outlines separating the vesiculose tissue of adjacent polyps. On account of the confused structure of this tissue these walls are then seen only on careful examination, but then they are marked enough. The interior of the polyp is filled with vesiculose tissue about the walls without traces of lamellæ, next comes a zone in which the vesiculose tissue is combined with radiating lamellæ, the vesicular tissue itself becomes more regular in arrangement and tends to combine in more or less circular rings around the more central portions of the polyp. Near the centre these rings usually become suddenly indistinct or entirely vanish. In this case they represent the more typical characters of the genus. In adjacent polyps the variation may be more gradual and then one of the more conspicuons characters of the genus fails. In one of the numerous polyps with this compound structure which may be taken as typical, the diameter of the entire polyp is 9 mm; the diameter as far as the exterior limit of the area of mixed lamellæ and vesiculose tissue is 5 mm. The diameter of the last easily seen ring at the interior limit of the vesicular tissue is 2.5 mm. Longitudinal sections show the vertical lamellæ towards the centre and the vesicular tissue quite strongly ascending forming on the average an angle of about thirty degrees with the centre of the polyp although this of course is very variable.

Spongophyllum Sedgwicki, Edwards and Haine in British Fossil Corals, plate 56, figure 2d, is a similar form but smaller. The Australian species is new. A description of the calyces is still necessary before science can be burdened wiih another name. When that is accomplished *spongohylloides* might not be an inappropriate term.

PLEURODICTYUM PROBLEMATICUM, *Goldfuss?*

(*Plate* XIII, *Fig.* 22.)

Fossils found in the form of casts. Corallum compound, composed of polyps intimately united by their walls. The walls are perforated, the perforations connect the cells of adjacent polyps. The base of the corallum is flat; there being no polyps here to connect the base of the corallum is flat; there being no polyps here to connect the casts show no traces of connecting perforations. This base of the corallum we know from analogy to have been covered by an epithecal membrane, but that part of the cast has not been seen. The upper surface of the corallum was broadly convex. The separate polyps were internally grooved longitudinally. The grooves are shallow, and rounded, and vary in number. There are usually from 25 to 30 of them in each polyp cell, and 10 to 12 of these are usually found on that side of the polyp which lies against the epithecal membrane in basal polyps. Between these grooves are raised areas or ridges, also rounded, bearing numerous low, round, pointed tubercles. They are so small that they do not merit the name of spines. These spines may occur as a single irregular series, or in two or three irregular series. Sometimes they are very irregular in arrangement, at other times the arrangement in series is very readily noticeable. All these variations take place in the same corallum. The earlier formed basal cells are usually pressed more or less out of shape below on one side, so as to form a pseudo-base. Those later formed have quite regular polygonal outlines, excepting that the side adjacent to the epithecal membrane is always larger than the rest. Diameter of base of corallum 29 mm. A much smaller specimen, 12 mm. broad presents every feature of the former excepting that there is a polyp cell in the centre flattened around the very base so that the pseudo-base is radiably striated, and the longitudinal ridges along the cell walls are more prominent. It seems however to be merely a young specimen.

In 1829, Goldfuss in Petref. Germ. published a fossil under the the name of *pleurodictyum problematicum*. This is entirely similar to the Australian species generically, differing however strongly in the possession of a tubular coiled body which is more or less interwoven with the base of the coralites. This body is found to be frequently not present and hence is regarded as only a parasitit organism and hence not a proper character of the genus.

In 1842, De Koninck established the genus *Michelinia*.

In 1851, Edwards and Haime in Polyp. Pal. associated under *Pleurodictyum problematicum Goldfuss* three distinct types. The first is that described by Goldfuss. The second consists of a colony of polyps without vertical ridges or series of tubercles. The third has vertical ridges but no tubercles. A fourth specimen had vertical ridges strongly marked; we do not however know whether it belongs to the first or third types.

In 1866 Mr. Rudolph Ludwig in Cor. aus Pal. Form. divided *Pleurodictyum* into two genera, giving each a new name, thus practically abolishing this genus. *Ptchychochartocyclus* contains those forms in which the interior walls of the polyp have longitudinal ridges, and these ridges are beset with distinct tubercles. *Taeniochartocyclus* contains those forms in which the ridges are not beset with tubercles but are smooth. They correspond to the first and third types of Edwards and Haime.

In Kentucky Fossil Corals, Mr. William J. Davis figures a new genus, *Procteria*. The figures seem to indicate the existence of mural pores connecting the polyps and also of tubercles ornamenting its interior. An examination of numerous specimens show that the character of the ridges is extremely variable in both tuberculated and non-tuberculated forms, and that they are often absent. At any rate we do not find in the figure of *Procteria* any thing to distinguish it from *Ptchychochartocyclus*, and this is only a synonym of *Pleurodictyum* even if it be indeed considered necessary to subdivide the genus. It will be therefore a matter of interest to learn what the forthcoming text may have to offer on that subject.

Forms have been referred to *Pleurodictyum problematicum* from various localities in North America and with a range from the Onondaga Group of New York to that of the Waverly Group in Ohio. We believe that on study these would be found to belong to several distinct species. Notwithstanding this range, the large celled forms of corals which pass under the name of *Pleurodictyum* are usually typical of Devonian strata, and are found there most frequently.

Pleurodictyum has been identified by Rominger and Lindstroem with *Favosites* and *Michelinia*. The type of the genus is more of the character of *Michelinia*. It seems to us therefore that *Pleurodictyum* has precedence over *Michelinia*. It contains typically the species of Goldfuss, the first type of Edwards and Haime, *Ptchychochartocyclus stigmosus*, *Ludwig*, and apparently the *Procteria* of Davis. If it be considered admissable to separate the forms without the tubercles, Ludwig's genus *Taeniochartocyclus* has the precedence.

We prefer also to retain the name *Pleurodictyum* for the Australian form in particular, because the vesiculose tissue of *Michelinia* has not as yet been seen in Australian specimens. For a discussion of the genus *Pleurodictyum* Nicholson's work, Pal. Tabulate Corals should be examined. The Australian fossils here described are part of a series kindly forwarded to us by Mr. John Mitchell of Bowning. They have all been obtained in the district near Bowning, New South Wales, Australia. The fossiliferous rocks here are all referred to the Upper Silurian Group They form a great synclinal basin from east to west. Near the base of the exposed series is a bed of hardened greyish-grown shale about 50 feet thick. This has furnished the tribolites the first two species of *Cyathophyllum* and the *Pleurodictyum*. Beneath this bed of shale is a layer of limestone containing many corals. From this we obtained *Cyathophyllum Boloniense* and the *Endophyllum*. The tribolites are all characteristic Silurian types. The corals have their nearest analogues in the Devonian formations. We find associated with the tribolites also two species of *Pinnatapora* or *Glanconome, Goldfuss*. Species of this genus usually occur in carboniferous and sub-carboniferous strata, and are not known to descend below the Devonian series elsewhere. It is evident from these remarks that a careful study of the fossils of this district would be an unusually valuable contribution to the study of paleontology.

CARBONIFEROUS.

CHAINODICTYUM LAXUM, *Foerste.*

Since the first publication of this species we have obtained good casts of the porifous face. This shows that the cell orifices are elongated and are arranged in oblique rows across the branches; their partition walls appear at the surface as more or less wavy, usually in osculating striæ. Two or three cells occupy the width of a branch.

McCoy in Carb. Foss. Ireland, published *Retepora undata* with the following description: "Irregularly cup-shaped, interstices anastomosing, flattened; fenestrule ovate, pointed at one end; poriferous face with five or six rows of pores in quincunx; reverse with waved or scale like, semicircular ridges. This species we have seen from Kildare and identify with our genus. The lunate cross-striations on the reverse side are also conspicuous. The cell apertures are similarly elongated and bordered by raised ridges. Compared with our species however the branches are much coarser and broader; being usually a millimetre (or slightly more) wide, whereas the branches of the American species have a width of .3 to .38 mm.

LOPHOPHYLLUM PROFUNDA. *Edwards and Haime.*

(————————)

In 1851, Edwards and Haime published in Polyp. Terr. Pal., under the name of *Cyathaxonia profunda* * a description of a coral collected at Flint Ridge, Ohio, which curiously enough was overlooked in preparing the catalogue of Flint Ringe fossils for the second volume of this bulletin.

Curiously enough both Edwards and Haime, and McChesney refer their species to *Cyathaxonia*, after *Lophophyllum* had been already established. To us indeed the two genera seem to be very distinct, but there is no doubt that the species here under consideration is far more closely allied to *Lophophyllum Konincki* than to *Cyathaxonia cornu*, the types of the two genera. In deference to the opinion of those who have made a special study of these genera we leave them separate, and refer our species to *Lophophyllum* as is the American custom at present. We believe however the *L. proliferum* is only one of the many varations of *L. profunda*, and should give place to the latter name.

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* "We know this species only by the interior cast of its calyx. The cast shows that the calyx was subcircular and deep; as it is more developed on the side of the septal fossette we think that the polyp was curved. The columnella is long and its transverse section subelliptical, 24 principal lamellæ quite large, well developed, alternate with an equal number of much smaller ones and arrange themselves about the columnella in a somewhat branched manner. Diameter of the calyx, 18 mm; its depth, 15."

This is really a very good characterization of Ohio specimens in the form in which they are usually found. But after considerable pains we found a few specimens which preserved the fossil itself. These in the last bulletin we identified with CYATHAXONIA PROLIFERA of McChesney. On Plate XII we figured the fossil itself, and on Plate II may be found an illustration of the cast.

PLATE XIII.

Fig. 1. *Phacops serratus, n, sp:* the head accidentally removed a little from the thorax in the rock.
Fig. 2. *Encrinurus Mitchelli, n. sp.* part of the head missing
Fig. 3. *Encrinurus Mitchelli, n. sp:* a fragment, showing the large tubercles at the dorsal furrow of the head; a typical specimen.
Fig. 4. *Lichas Halli, n sp.*
Fig. 5. ·*Microdiscus punctatus Salter;* head, Museum Com. Zoology, Harvard Univ.
Fig. 6. *Sphærexochus mirus, Beyrich;* a glabella and fixed cheek.
Fig. 7. *Encrinurus Bowningi, n. sp.* glabella and fixed cheeks.
Fig. 8, *Lichas Trentonensis, Conrad:* head, outline, Mus. Comp. Zool.
Fig. 9. *Cyathophyllum patula, n. sp;* a cross-section of unusually wrinkled form.
Fig. 10. *Cyathophyllum patula, n. sp;* the lower side of two polyps.
Fig. 11. *Cyathophyllum patula, n. sp.*; a few lamellæ enlarged.
Fig. 12. *Cyathophyllum australe n. sp.* the exterior of the calyces seen from a cast, partly restored.
Fig. 13. *Cyathophyllum australe n. sp*; a cast.
Fig. 14. *Cyathophyllum australe n. sp*; a few lamellæ and grooves enlarged.
Fig. 15. *Cyathophyllum Boloninense, Blainville;* a cross-section.
Fig. 16. *Endophyllum* (*sphongophylloides?*) a cross-section.
Fig. 17. *Endophyllum;* the same, a vertical section.
Fig. 18. *Strombodes pygmæus, Rominger;* part of a corallum collected by Mr. John Van Cleve.
Fig. 19. *Encrinurus punctatus, Brunswick;* a European specimen, figure taken from the work Fr. Schmidt, on East Baltic Silurian Trilobites.
Fig. 20. *Encrinurus Mitchelli, n. sp;* a moveable cheek.
Fig. 21. *Lichas breviceps, Hall, Waldron.* Indiana, Mus. Comp. Zool.
Fig. 22. *Pleurodictyum problematicum, Goldfuss?* View of base of casts, the epitheca being gone.

ERRATA.

Page 122, instead of *Encrinurus Browningi* read *E. Bowningi.*
Page 132, instead of *Spongopylloids* read *Spongophylloides.*

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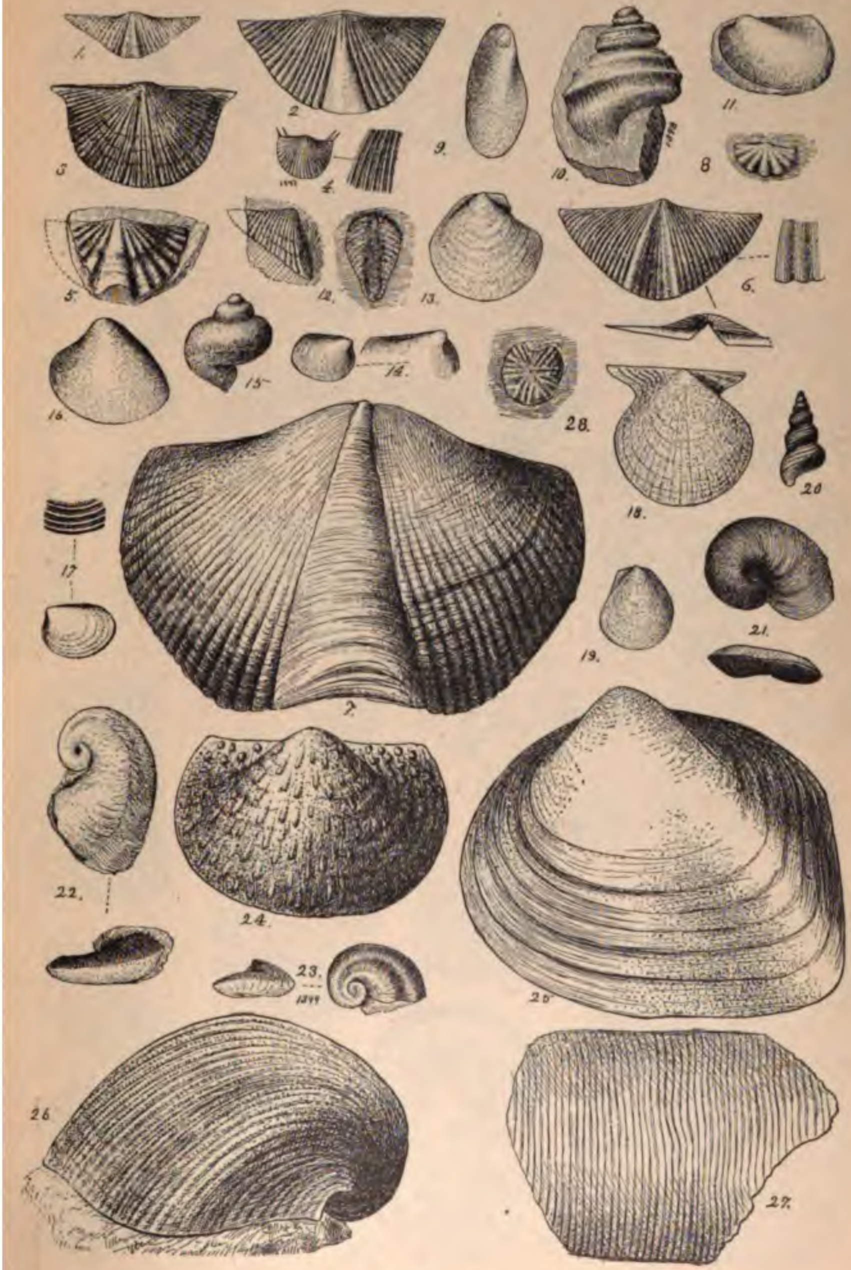

PLATE I.

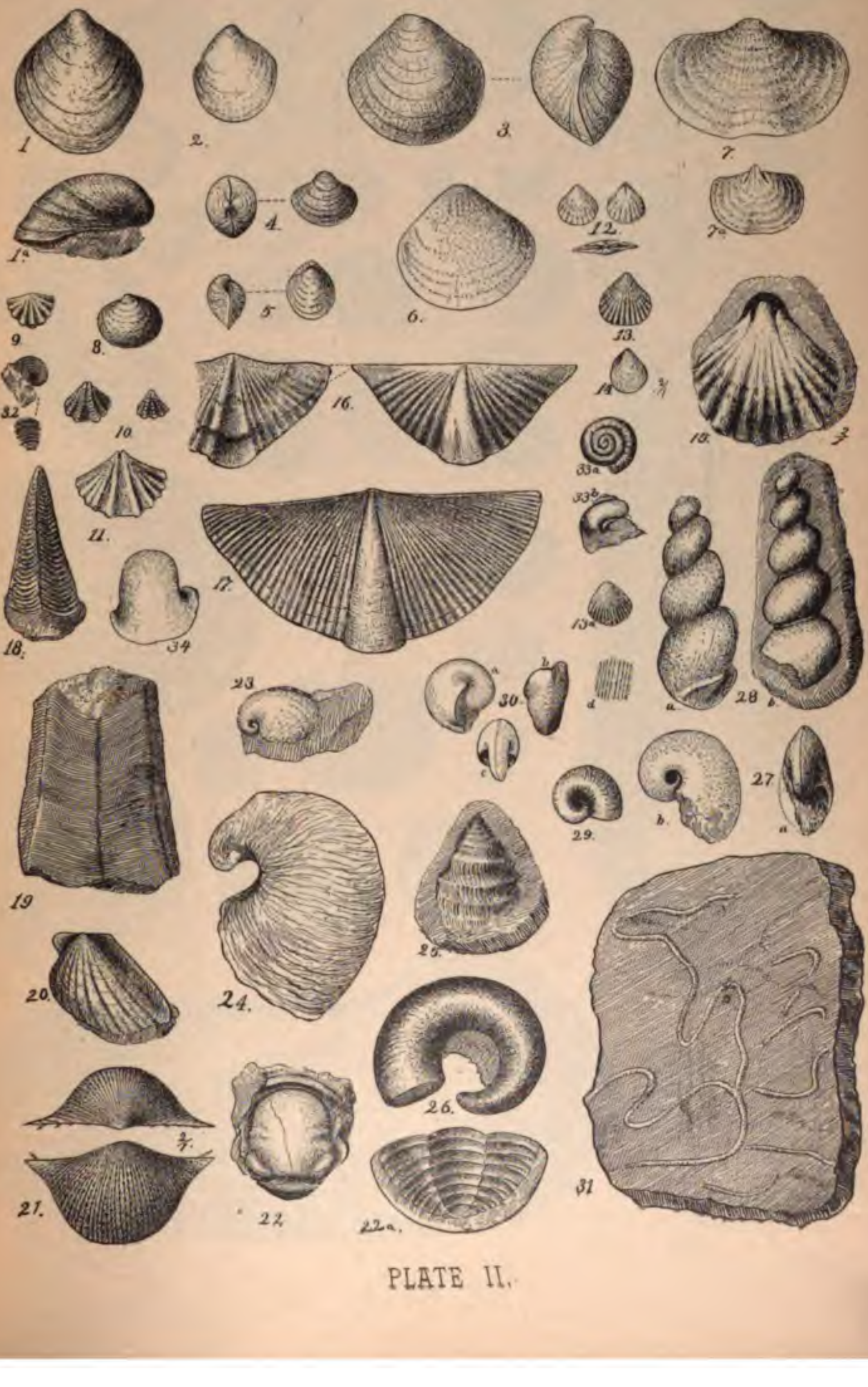
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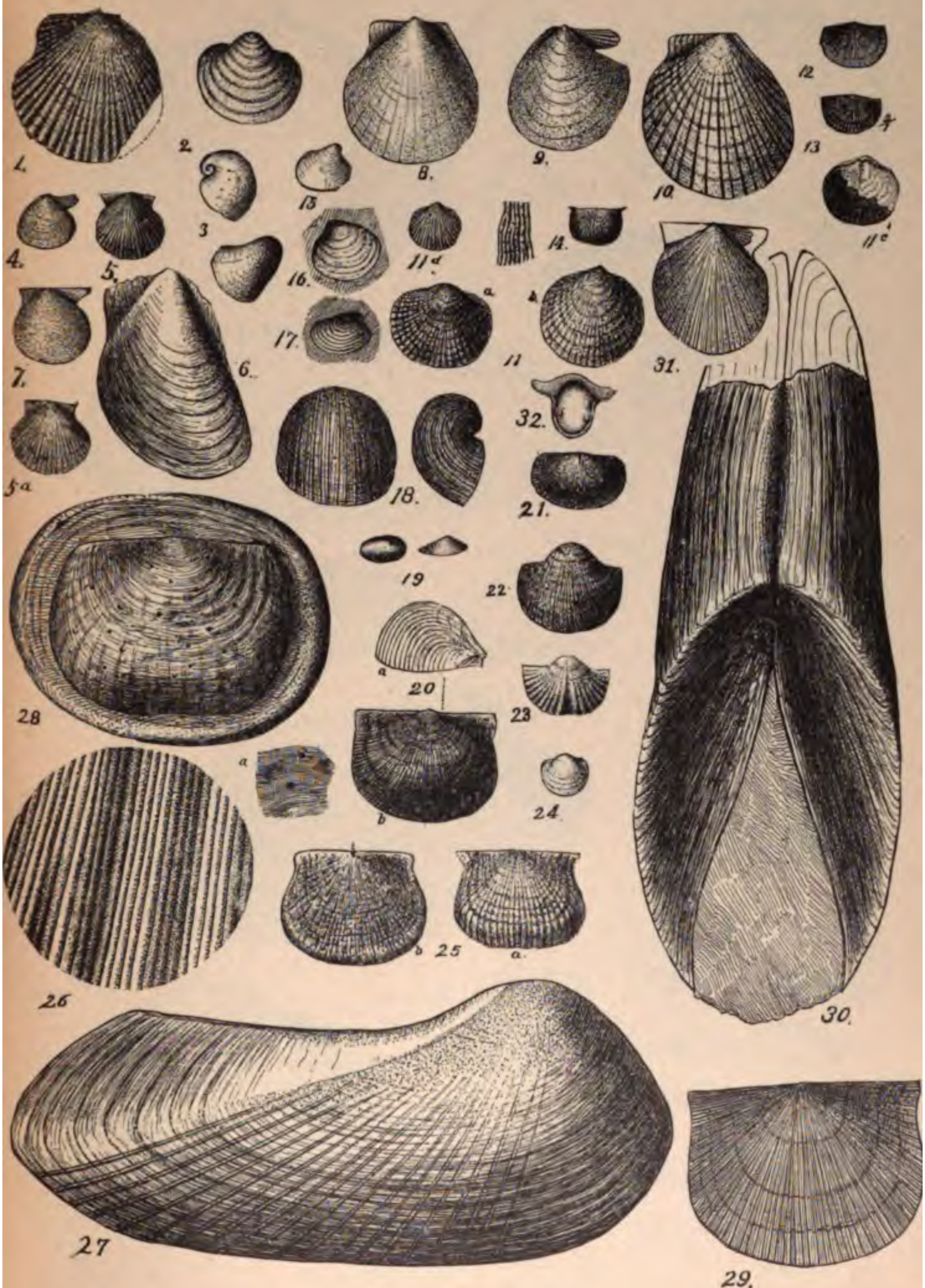
PLATE II.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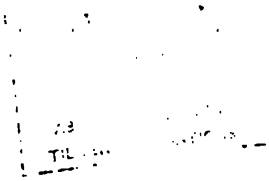

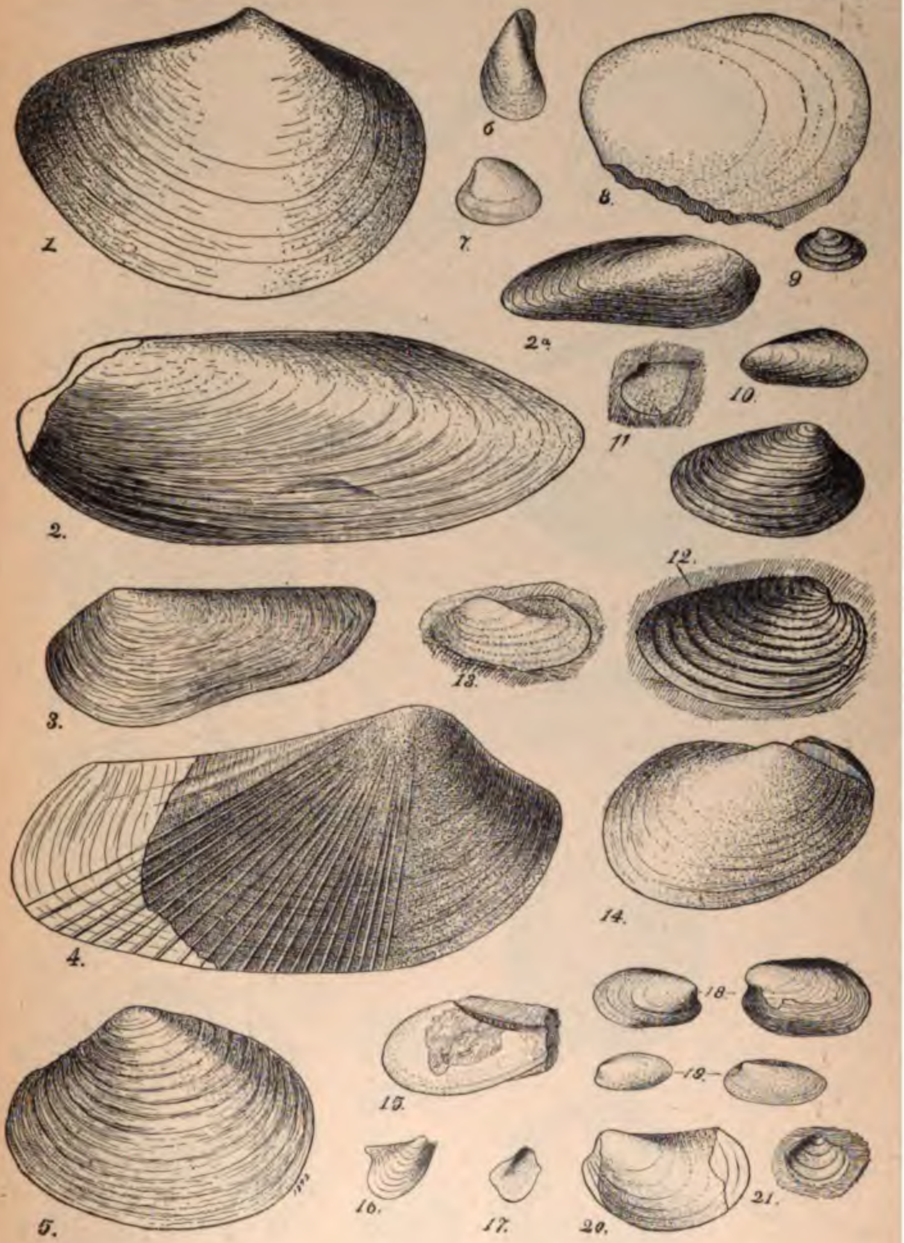

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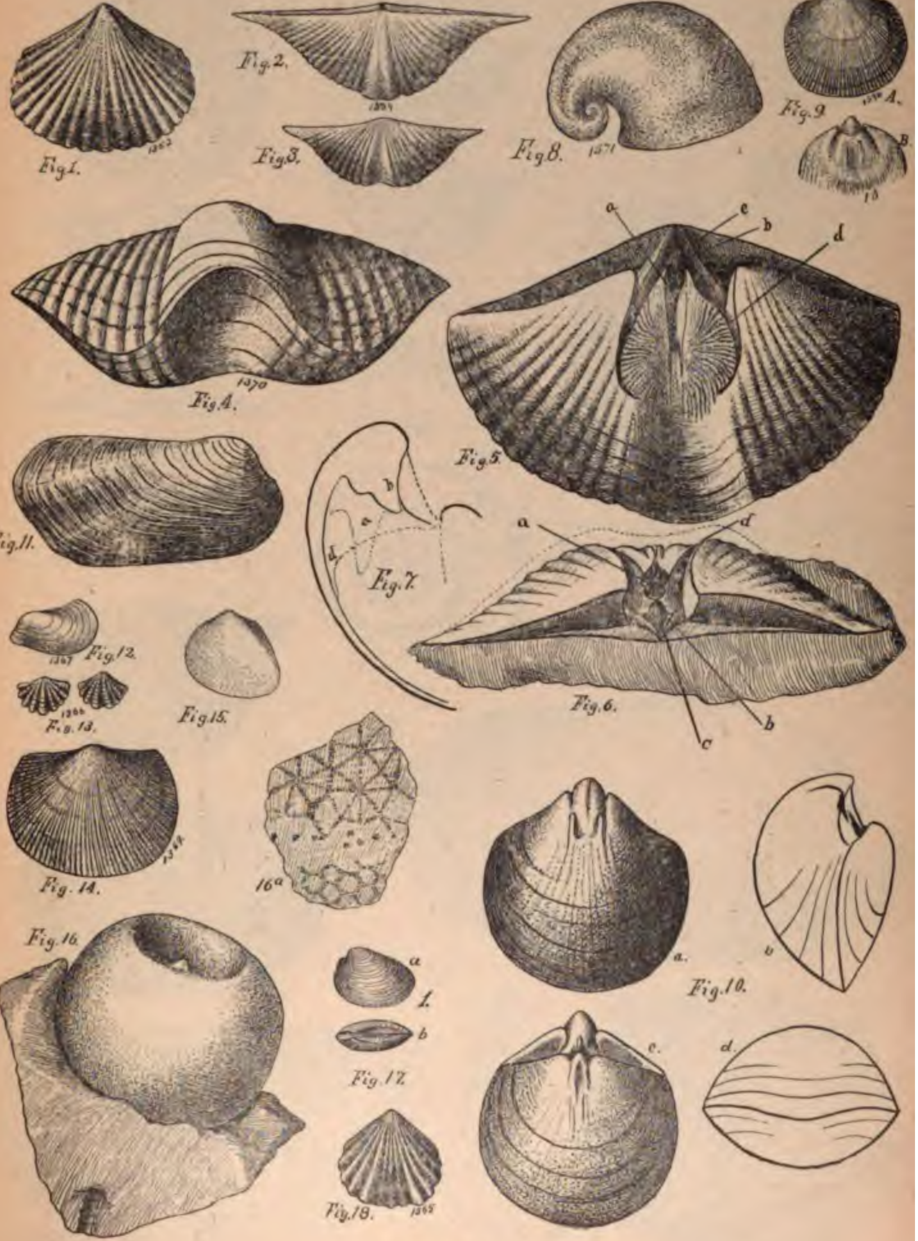
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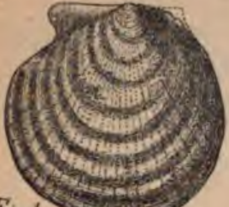
PLATE V.



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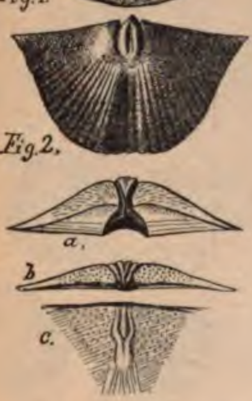

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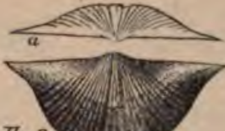

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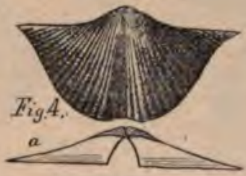

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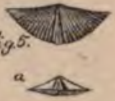

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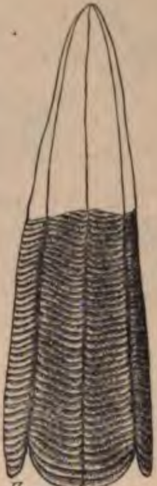

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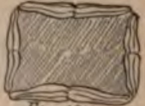

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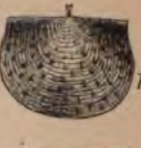

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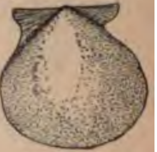

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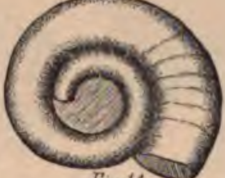

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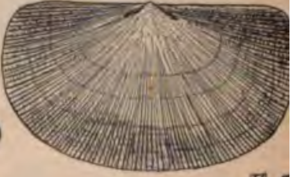

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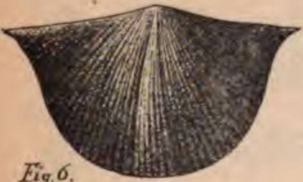

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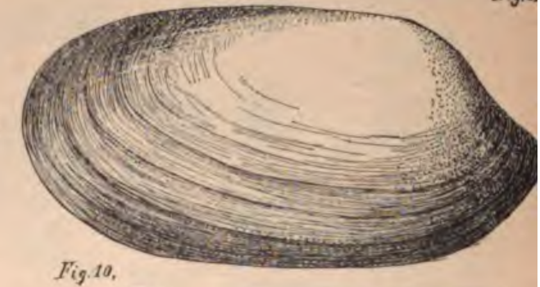

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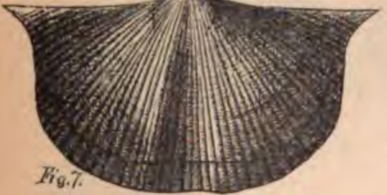

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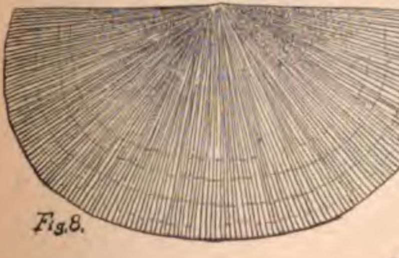

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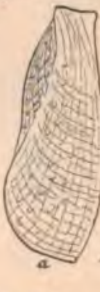

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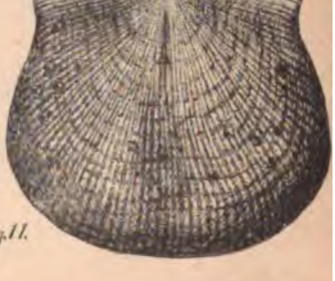

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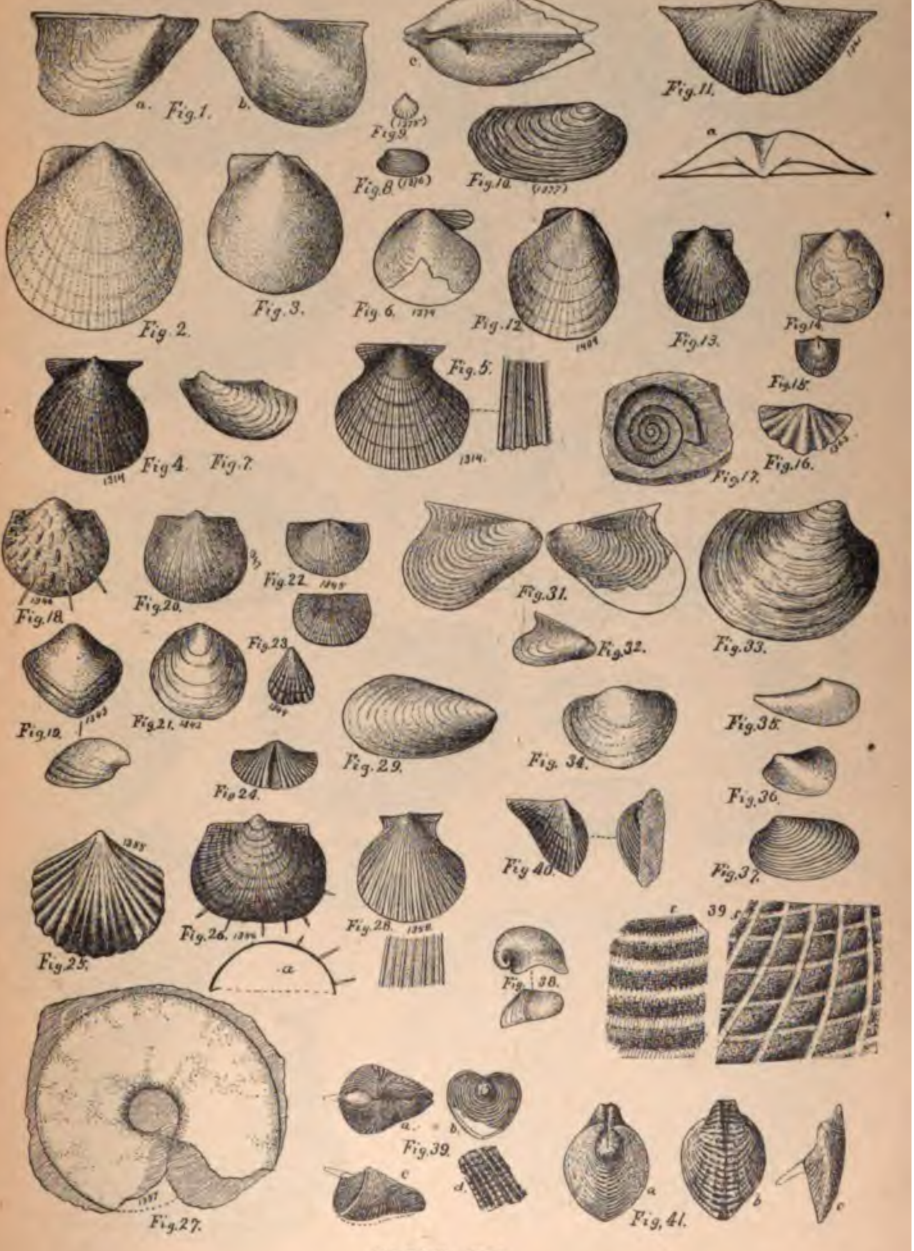
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PLATE VII.

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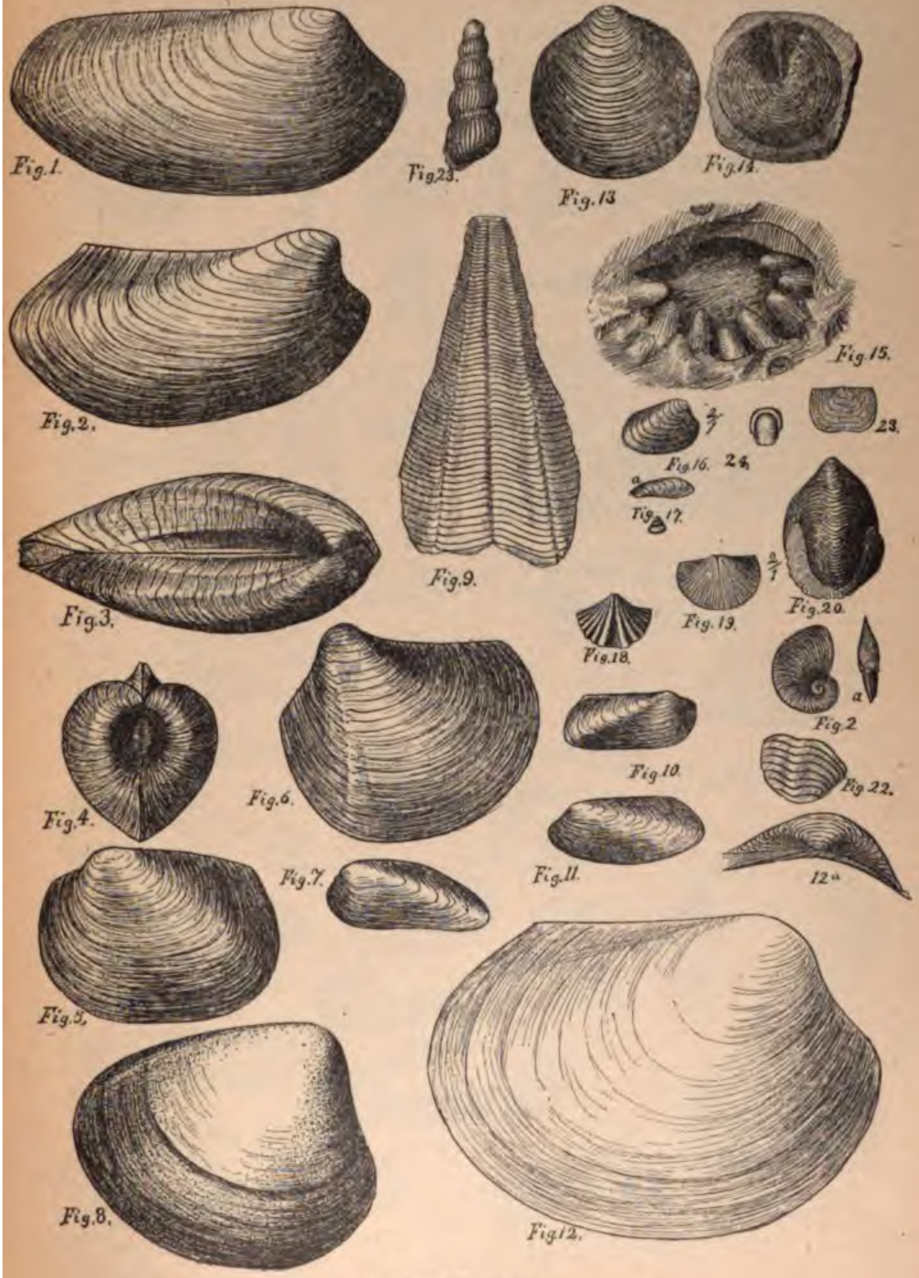
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PLATE VIII.

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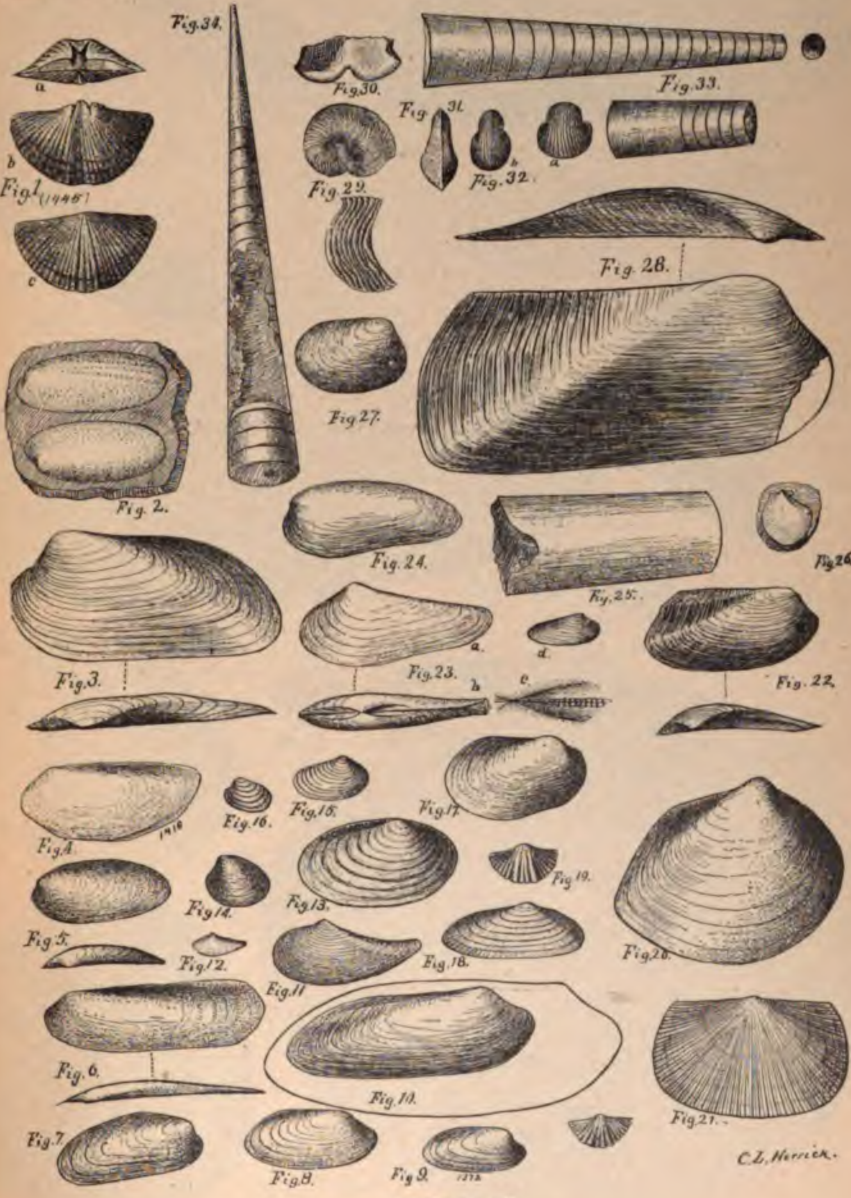
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C. L. Herrick.

PLATE IX.

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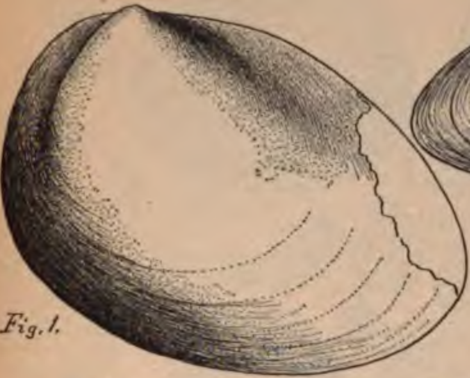

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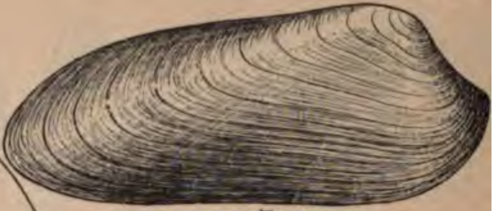

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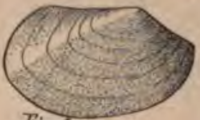

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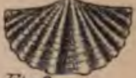

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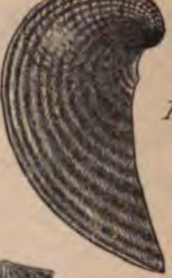

Fig. 6.

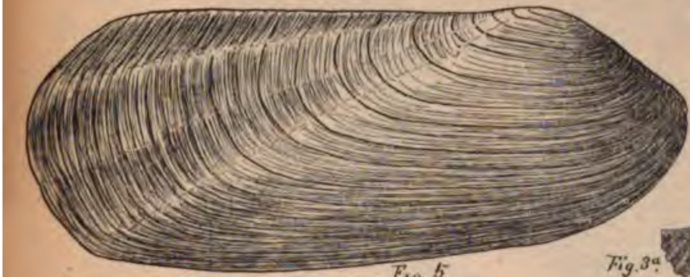

Fig. 5.

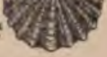

Fig. 3a.

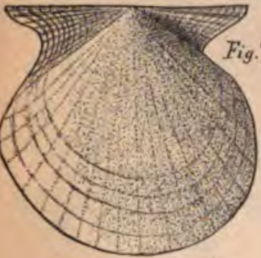

Fig. 7.

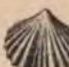

Fig. 9.

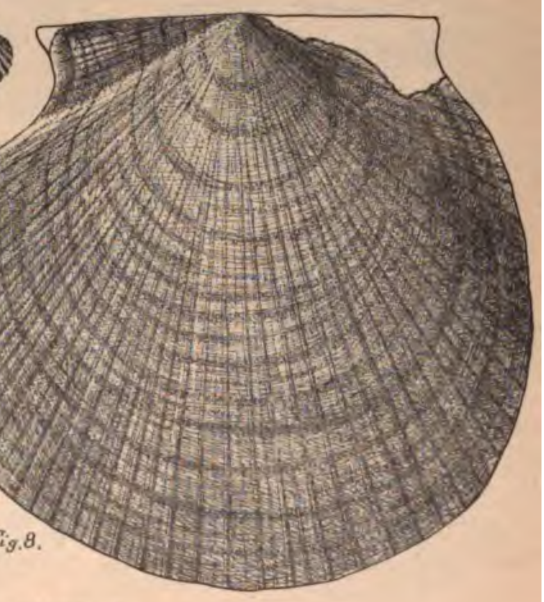

Fig. 8.

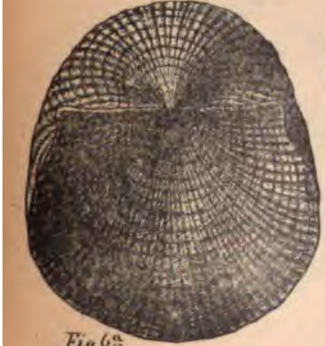

Fig. 6a.

PLATE X.

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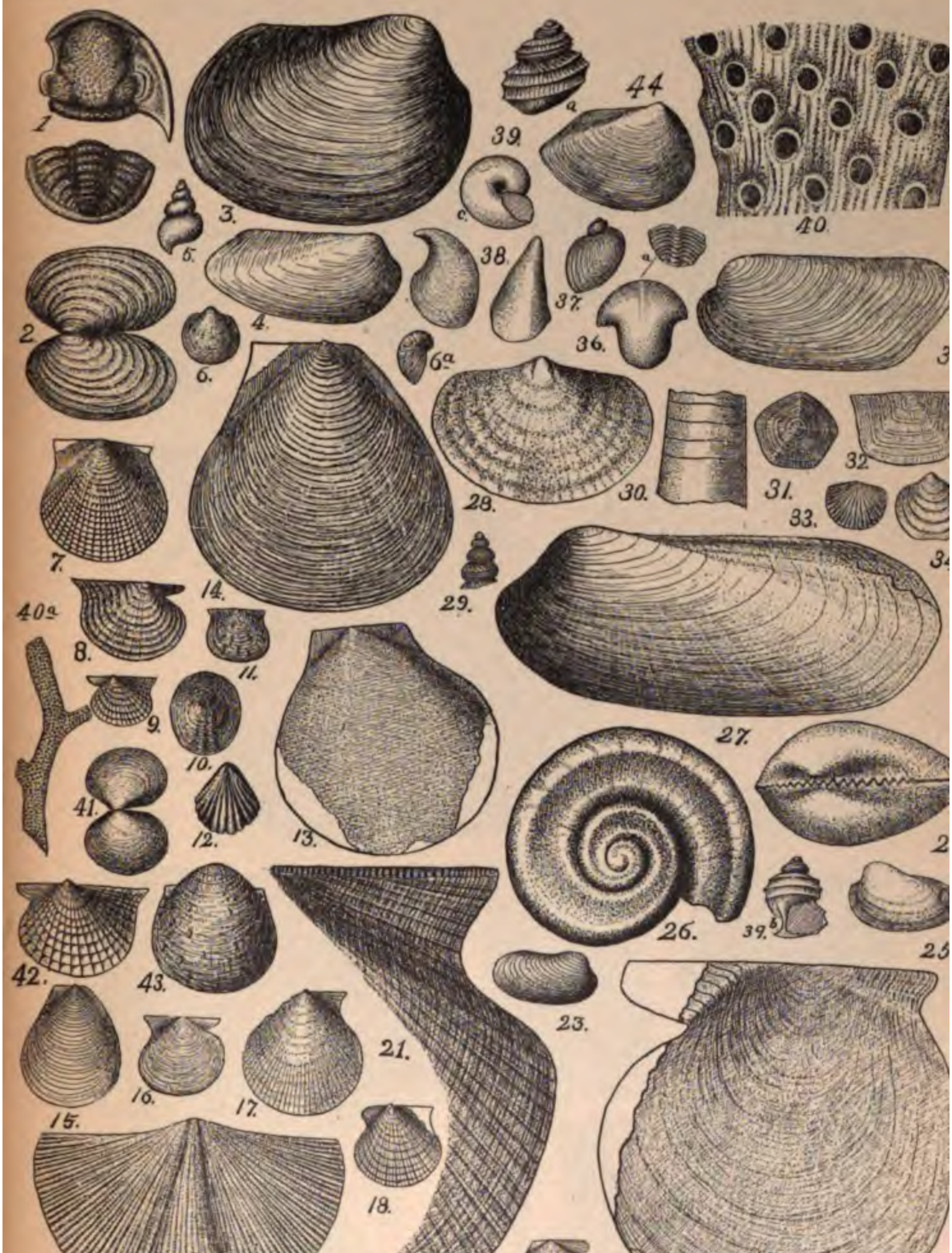
ASTOR, LENOX AND
TILDEN FOUNDATIONS


1
3.
39
a
44
c.
40
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37
a
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4.
36.
3
6.
6a
28.
30.
31.
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34
40a
8.
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PLATE XII.

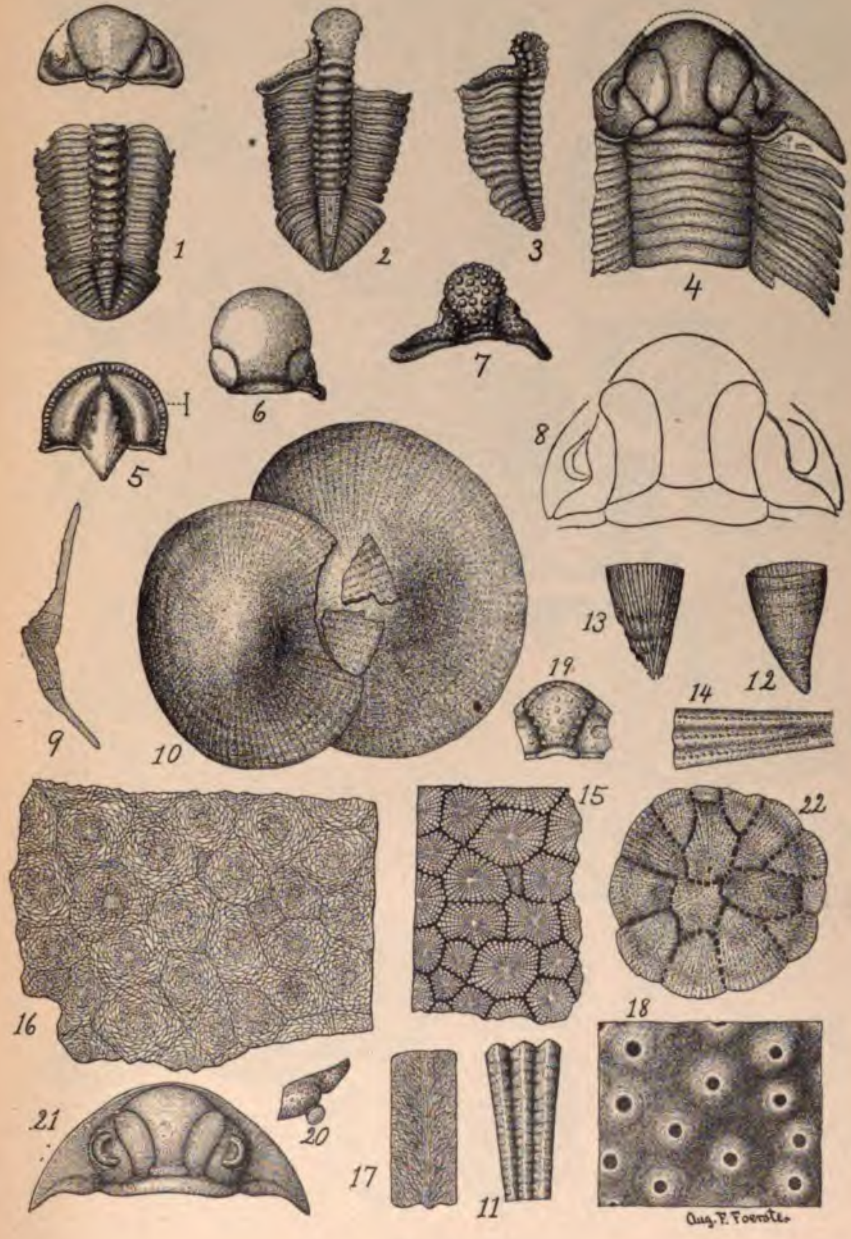

PLATE XIII.

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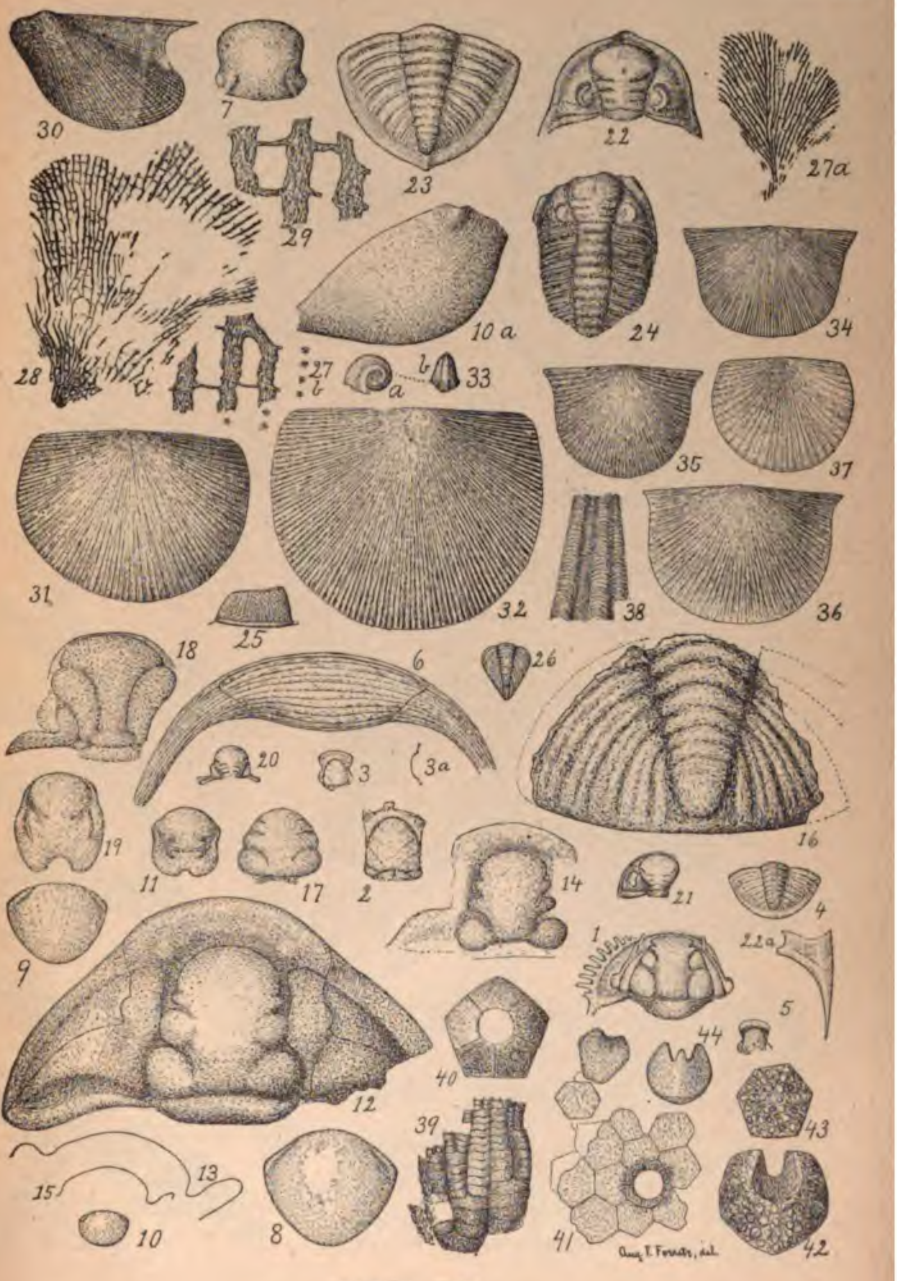
30
7
23
22
27a
29
28
10 a
24
34
27
b
a
b
33
31
32
38
35
37
36
25
18
6
26
20
3
3a
16
19
11
17
2
14
21
4
9
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22a
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42
Aug. F. Foerste, del.

PLATE VIII.

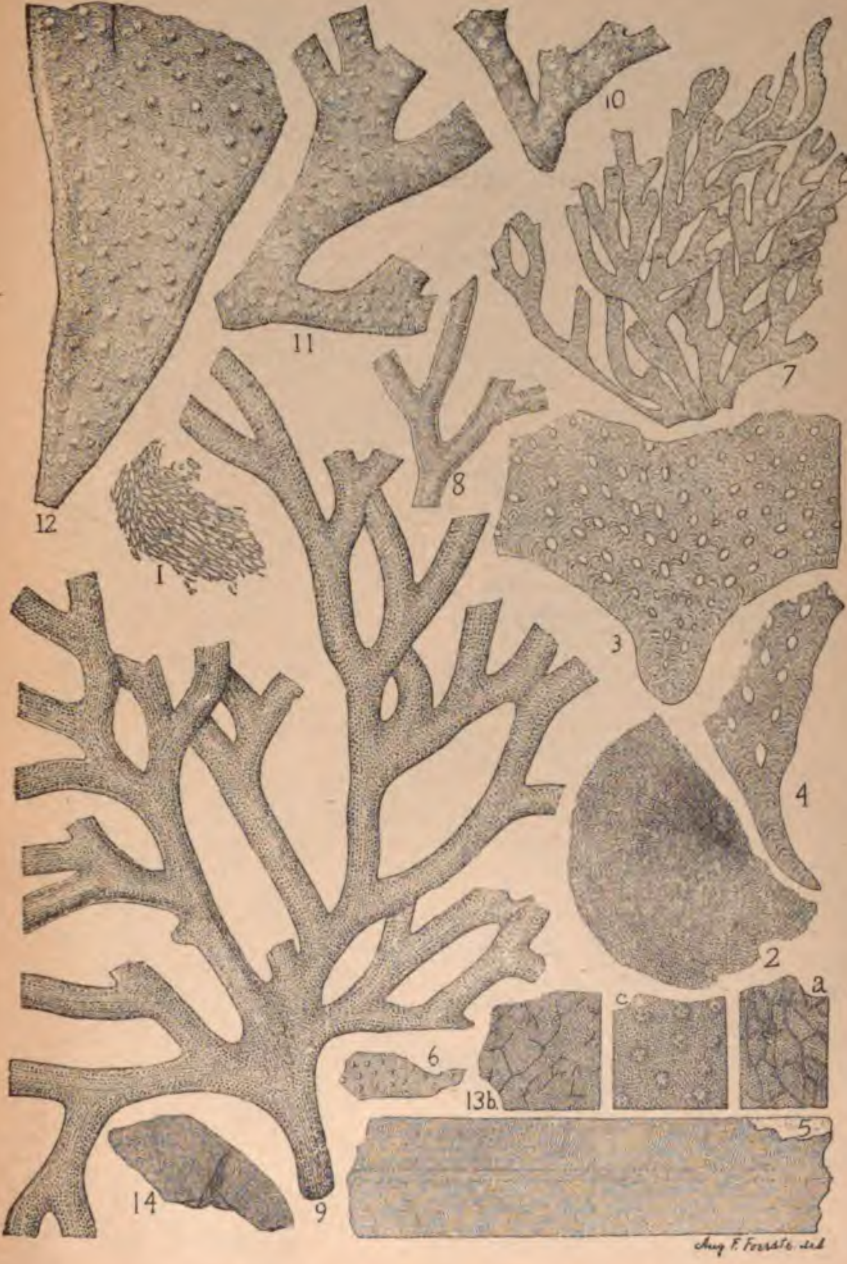

PLATE XV.

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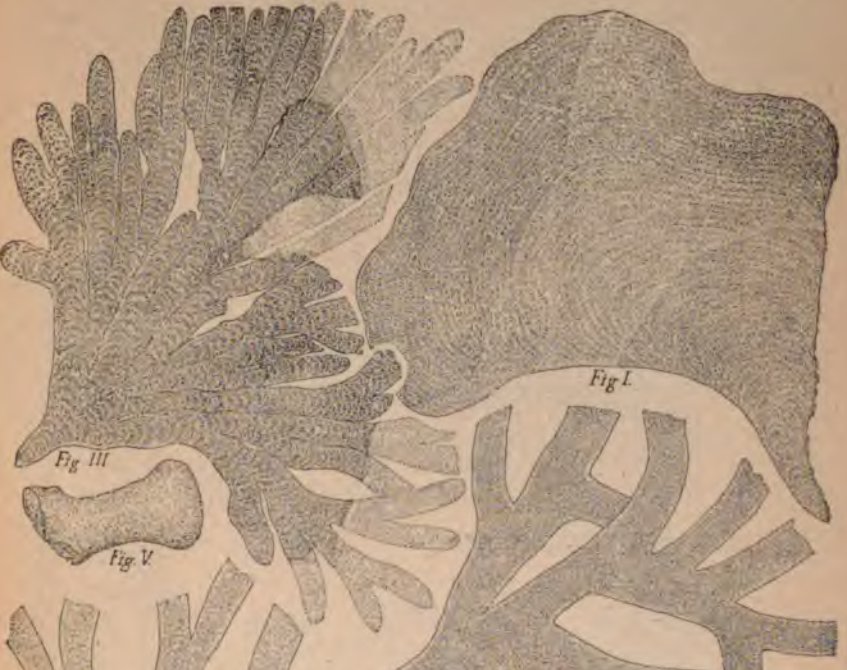
Fig I.
Fig III
Fig. V.
Fig II b
Fig IV b
Fig IV a
Fig II a
Fig VI
Fig II c
Aug. F. Foerste, del.

PLATE XVI.

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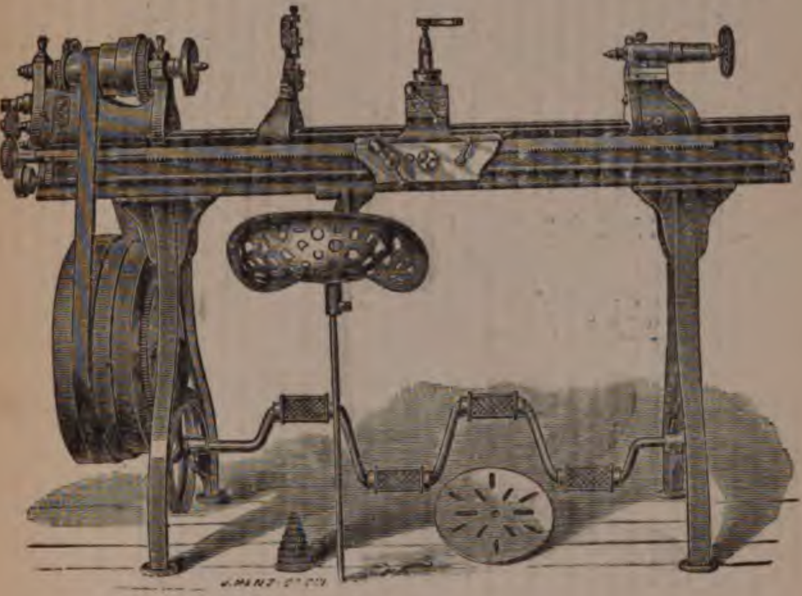
BARNES'

PATENT

Foot Power Machinery



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